MONITORING REPORT FOR 2017

CLARK FORK RIVER OPERABLE UNIT

prepared for

Montana Department of Environmental Quality
Waste Management and Remediation Division
Federal Superfund and Construction Bureau
1225 Cedar St. | P.O. Box 200901
Helena, MT 59620-0901

September 2018

RESPEC

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by

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EXECUTIVE SUMMARY

This performance monitoring program evaluates the progress of remedial actions in the Clark Fork River Operable Unit (CFROU) of the Milltown Reservoir/Clark Fork River Superfund sites toward meeting performance goals or identified reference values. Environmental media monitored in 2017 included surface water, instream sediment, periphyton, macroinvertebrates, periphyton, fish, birds, and vegetation. This report summarizes results of data collected for each of these environmental media and evaluates progress toward attainment of performance goals or in relation to reference values as of 2017.

Environmental damages to the upper Clark Fork River were summarized in the Record of Decision (ROD) for the Clark Fork River Operable Unit. Contamination occurred due to heavy metals originating from historic mining, milling, and smelting processes associated with operations in Butte and Anaconda. Metal contaminants accumulated in the Clark Fork River streambanks and floodplain over a period of at least 100 years. The primary sources of contamination were tailings and contaminated sediments mixed with soils in the streambanks and floodplains, which eroded during high streamflow events and entered the river and other surface waters. In addition to erosion, heavy metals were leached from the contaminated sediments and tailings directly into the groundwater and eventually to surface water. These contaminant transport pathways resulted in impacts to terrestrial and aquatic life along the Clark Fork River.

The Montana Department of Environmental Quality (DEQ), as lead agency and in consultation with the U.S. Environmental Protection Agency (USEPA) and the National Park Service, oversees, manages, coordinates, designs, and implements remedial actions for the Clark Fork River site. DEQ coordinates with the Natural Resource Damage Program (NRDP) of the Montana Department of Justice regarding implementation and integration of restoration components to supplement the remedial actions. DEQ coordinates with the National Park Service to implement remedial actions on the Grant-Kohrs Ranch.

Data collected in 2017 represents the eighth year of monitoring in the CFROU. Monitoring under this program was first conducted by DEQ and RESPEC personnel in the spring of 2010, prior to initiation of any remediation actions within the CFROU. Since 2010, some monitoring sites have been added to the monitoring program in Clark Fork River tributaries. In addition, this monitoring program has been coordinated with long-term monitoring by the U.S. Geological Survey (USGS) to complement data collected by the USGS and minimize data duplication by each program. Monitoring methods and quality assurance protocols guiding collection and analysis of the data described in this report are summarized in the project sampling and analysis plan (SAP) and the project quality assurance project plan (QAPP).

The CFROU monitoring network for surface water, sediment, and some aquatic biota (macroinvertebrates and periphyton) included seventeen sample sites; seven mainstem sites and ten tributary sites. Not all sites were sampled for each environmental medium or for each analyte of each medium (e.g., some surface water sites were only sampled for mercury and methylmercury rather than the full suite of analytes). The monitoring network has been largely consistent since 2014. One new site in the Clark Fork River mainstem (CFR-34; Clark Fork River at Williams-Tavenner Bridge) was added in 2015 downstream from the Grant-Kohrs Ranch National Park property. Site CFR-34 was added to provide a more detailed assessment of water and instream sediment chemistry and aquatic biota that may be related to upcoming remedial actions in Phases 15 and 16. One site Silver Bow Creek at Frontage Road (SS-19) is sampled as part of the Streamside Tailings Operable Unit monitoring program during some sample periods and as part of the CFROU monitoring program during other sample periods.

Surface water and instream sediment monitoring is primarily intended to describe concentrations of metal contaminants of concern (COCs; arsenic, cadmium, copper, lead, and zinc). For surface water, additional data was collected including nutrient and common ion concentrations, and other field parameters (e.g., pH). Surface water samples were collected during each calendar quarter with two additional monitoring periods during the spring snowmelt runoff period. Sediment samples were collected during the first (late winter) and third (late summer) quarter sample periods. Macroinvertebrate and periphyton samples were collected during the summer (third quarter). Fisheries data, collected by Montana Fish Wildlife and Parks, included trout population monitoring, microchemistry, wild fish tissue burdens from metals, *in situ* mortality of confined fish at selected sites, and stream chemistry data. Bird monitoring data, collected by GoBirdMontana, included monitoring of bird species richness and relative abundance in Reach A of the CFROU.

Streamflows in the upper Clark Fork River watershed were normal to slightly higher than normal during the spring through the snowmelt period (i.e., end of June) in 2017 due to above normal snowpack. However, following subsidence of the runoff a prolonged drought occurred and streamflows were generally below normal during the summer and fall. Some sites had severely low streamflows in 2017. Summer streamflows at Deer Lodge were 20-30 percent lower than normal and the duration of those low streamflows extended well into September which is far longer than normal. The annual minima at Flint Creek reached 7 cubic feet per second, or approximately one third of the long-term median at that site.

Surface water COC concentrations in the mainstem exceeded performance goals for all COCs in at least one sample but were most frequent for arsenic. Of 36 samples collected in the Clark Fork River mainstem in 2017 (from six sites during six sample periods), performance goal exceedances occurred for zinc in one sample (3 percent), for cadmium and copper in two samples (6 percent), for lead in ten samples (28 percent), and for arsenic in 20 samples (56 percent). Arsenic exceedances were most consistent in Reach A during Q2 and Q3. Silver Bow Creek (below the Warm Springs Ponds) and Mill-Willow Creek were clearly sources of arsenic to the Clark Fork River as 75 percent (18 of 24) of the samples from sites in those stream sections exceeded the arsenic performance goal. Arsenic concentrations in Silver Bow Creek entering the Warm Springs Ponds (at Frontage Road) were always considerably lower than the concentrations leaving the ponds (at Warm Springs) indicating that arsenic is likely remobilized in the ponds.

Exceedances of the more restrictive reference value for sediment COC concentrations (the "Threshold Effect Concentration"; TEC) occurred in all 2017 CFROU mainstem and tributary samples for all COCs except for one third quarter sample from Racetrack Creek. Exceedances of the more lenient reference value (the "Probable Effect Concentration"; PEC) were also quite common for all COCs. In Silver Bow Creek and Mill-Willow Creek, exceedances of the PECs were generally just as frequent as in the mainstem sites. All samples exceeded the PEC for each COC. Warm Springs Creek exceedances of the PEC occurred, but less frequently compared to the mainstem, Silver Bow Creek, and Mill-Willow Creek sites. Exceedances of the PECs were less common in Lost Creek and Racetrack Creek and the Little Blackfoot River did not exceed the PEC for any COC. In the Clark Fork River mainstem since 2014, the highest cationic COC concentrations (cadmium, copper, lead, zinc) have tended to occur in the upper-most portion of Reach A (near Galen) and have generally decreased with downstream distance from the near Galen site. Arsenic concentrations in the mainstem also decreased with downstream distance from site CFR-03A but the decrease with distance was even more pronounced.

Periphyton monitoring included, among other assessment tools, DEQ-recommended bioindices designed to evaluate the probability of impairment from sediment, metals, and nutrients to the diatom assemblage at each sampled site. In the mainstem, impairment probability determined to be more likely than not (i.e., more than 50 percent) for each stressor of interest (sediment, metals and nutrients) at all sites except at Deer Lodge (and at Turah for sediment). The Silver Bow Creek, Mill-Willow Creek, and Little Blackfoot River sites also tended to have high impairment probability for each of those stressors whereas impairment probabilities were relatively low in Warm Springs Creek, Lost Creek, and Racetrack Creek. Although these impairment ratings are compelling, we observed that most stressor-specific bioassessment scores had no statistically significant relationship with water quality measurements representing each stressor of interest. The general lack of correlation may be due to a high degree of variability in the data, a low number of observations, or because of interference of multiple environmental-stressors which obscures the ability of the stressor-specific indices to identify specific impairments from a particular stressor. Although most bioindex scores did not appear to be related to the water quality measures, a statistically significant relationship was observed between the relative abundance of nitrogen-heterotroph (i.e., organic nitrogen tolerant) species and organic nitrogen concentrations.

Macroinvertebrate monitoring also included a variety of bioassessment tools which were applied to the taxonomic analysis results for each sample. The same suite of bioassessment tools was applied to each sample. The various bioindex results were consistent for some samples whereas for other samples the various bioindex results produced inconclusive or contradictory results. The macroinvertebrate community at all sites (except Racetrack Creek) was determined to be stressed from habitat instability. Sedimentation was deemed a stressor in both Silver Bow Creek sites and in Lost Creek. Metal contamination was deemed to be a stressor in Silver Bow Creek at Warm Springs and in Lost Creek. Results of nutrient impairment were quite mixed and often not in agreement among the indices.

Montana Fish, Wildlife, and Parks conducted a variety of fish monitoring activities in 2017. As in prior years, mortality was highest immediately below the Warm Springs Ponds and likely causes appear to be high summer water temperatures and pH. Population monitoring results in 2017 indicate that brown trout abundance in the upstream-most portions of the Clark Fork River (near where remediation is occurring) is low compared to the long-term average. In contrast, abundance at downstream sites was similar to, or higher than, prior years.

In addition to annual mortality and population monitoring, FWP monitored fish movement and recruitment. Otolith (i.e., inner ear bone) microchemistry analysis was used to identify movement patterns of harvested fish. Otoliths were harvested from a sample of fish and based on the chemistry of those bones the fish's movement history (since hatching) was determined. This approach allowed FWP to identify important tributaries and portions of the Clark Fork River that were important for recruitment. Generally, brown trout adults captured in the mainstem hatched and reared in areas (either tributary or mainstem) near where they were captured. Reach A was identified as an important spawning area for brown trout in that portion of the river. In addition, Mill-Willow Creek appeared to be an important spawning tributary for brown trout. The Little Blackfoot River, surprisingly, did not appear to be important despite contrary evidence from prior studies.

Bird monitoring has been conducted annually since 2015. Results indicate that the CFROU provides habitat for a large number of bird species including multiple Montana Species of Concern. Bird monitoring has focused on the Reach A section from Phase 1 to Phase 16. Since 2015, 115 bird species have been identified in the CFROU. Species richness, after adjusting for sampling effort, was generally similar among phases although Phases 4 and 7 appeared to have a bit higher richness than others and Phase 1 appeared to have a bit lower richness. Increased richness in Phase 7 was likely due to the Racetrack Pond which provides a unique habitat. Lower richness in Phase 1 may be due to the intensity of construction activities that occurred in that river reach during the monitoring period, the relative lack of vegetation in the initial years after construction, or other factors. Fourteen Montana Species of Concern in Montana have been observed in the CFROU since 2015. Phases 7 and 15 were particularly rich in these rare species but all phases had at least one Species of Concern.

Vegetation monitoring occurred in Phases 2, 5, and 6 in 2017 and represented Year-1 (post-remedy) conditions in each phase. Vegetation establishment and vigor was almost certainly reduced in 2017 due to severe summer drought conditions in the upper Clark Fork River basin. Monitoring occurred in mid-August and was preceded by a 63-day drought. Woody plant survival was slightly below the performance target (90 percent) in Phases 2 and 6 (87 percent in each) and more substantially below the target in Phase 5 (72 percent). Perennial vegetation cover was low (less than 38 percent) in all vegetation zones of all phases compared to the performance target (90 percent for the Riparian and Transition Zones). The perennial vegetation cover proportion from undesirable species was typically 20-30 percent of the total cover in the Riparian and Transition Zones monitoring plots. The undesirable species contributing the greatest amount of cover were Mexican kochia, sweet clover, and cheatgrass. Desirable species contributing the greatest amount of cover was common yarrow, oakleaf goosefoot, narrowleaf willow, Baltic rush, bulrush, slender wheatgrass and other grasses. Noxious weeds were generally well controlled. Mean noxious weed cover was less than 2 percent in each vegetation zone in each phase. Observed noxious weed species included leafy spurge, yellow flag iris, perennial pepperweed, and knotweed.

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1.0 INTRODUCTION

The Record of Decision (ROD) for the Clark Fork River Operable Unit (CFROU) identified a 120-mile section of the Clark Fork River as a distinct Superfund Operable Unit [USEPA, 2004]. The CFROU extends from the Silver Bow Creek and Warm Springs Creek confluence to the former Milltown Reservoir site at the Clark Fork River and Blackfoot River confluence (Figure 1-1). Historic mining, milling, and smelting activities in Butte and Anaconda resulted in heavy metal (cadmium, copper, lead, and zinc) and arsenic contamination in the floodplain soils and streambanks of the CFROU. Sources of metal contaminants of concern (COCs) in the CFROU are tailings mixed with soil within the historic 100-year floodplain (the primary source), contaminated surface water and shallow groundwater, contaminated instream sediments, and contaminants in irrigation ditches adjacent to the CFROU [USEPA, 2004]. In 2008, a consent decree was negotiated between the state of Montana, the U.S. Government, and the Atlantic Richfield Company for cleanup of the CFROU [Montana v. AR, 2008; U.S.A. v. AR, 2008]. The consent decree established that the state of Montana, through the Montana Department of Environmental Quality (DEQ), would serve as lead agency to develop and implement the remedial design, remedial actions, and operation and maintenance of the remedy for the CFROU [Montana v. AR, 2008; U.S.A. v. AR, 2008].

Specific remediation standards were establishend in the CFROU ROD for surface water, groundwater, and vegetation but not for other environmental media [USEPA, 2004]. In lieu of specific standards, reference values have been adopted by DEQ for instream sediment, geomorphology, periphyton, macroinvertebrates, and fish. DEQ has established this monitoring program to assess the effectiveness of contaminant removal from remediation on attainment of remediation standards or reference values. Data is collected to describe abiotic (surface water, instream sediment, river geomorphology) and biotic (terrestrial vegetation, periphyton, aquatic macroinvertebrate, and fish) conditions in the CFROU to evaluate if remediation standards or reference values are met and evaluate if conditions are improving over time. Data collected in 2017 represents the eighth year of data collected for this monitoring program, which began in 2010. The following paragraphs provide a summary of remedial work conducted in the CFROU to date.

Remediation activities in Phase 1 (Figure 1-2) of the CFROU began in 2013 and project construction was completed in spring 2014. Revegetation in Phase 1 was completed in fall 2014. Phase 1 consists of the upstream-most 1.6 river miles of the Clark Fork River, immediately downstream from the Warm Springs Creek and Silver Bow Creek confluence. In total, approximately 330,000 cubic yards of contaminated material was removed from a 60-acre project area.

Remediation of Phase 2 (Figure 1-3) began in the summer of 2015 and construction was in progress throughout the remainder of the year. Phase 2 consists of the river banks and floodplain along a 1.9 river mile section (88 acres) of the Clark Fork River, immediately downstream from Phase 1. Construction activities in Phase 2 were completed in 2016. Revegetation activities were also completed in fall 2016. The volume of contaminated material removed from Phase 2 was approximately 403,000 cubic yards.

Remedial plans for Phases 3A, 3B, and 4 (Figure 1-4) are currently in the design phase. These phases together consist of a 4.5-mile river length and an accompanying floodplain area of 261 acres. Construction activities for Phase 3A are anticipated to begin within five years.

Remediation of Phases 5 and 6 (Figure 1-5) began in the summer of 2014 and construction was in progress throughout 2015. Phases 5 and 6 consist of the river banks and floodplain along a 4.3 river mile section (125 acres) of the Clark Fork River, immediately downstream from Phase 4. Construction and revegetation activities were completed in Phases 5 and 6 in 2016.

Remedial plans for Phase 7 (Figure 1-6) are currently in the design phase. Phase 7 consists of a 1.9-mile river length and an accompanying floodplain area of approximately 84 acres.

Remedial plans for Phases 8 and 9 (Figure 1-7) are currently in the sampling and site characterization phase. Phases 8 and 9 consist of a 5.1-mile river length and accompanying floodplain area.

Remediation occurred in 2012 and 2015 in the "Eastside Road" pasture areas adjacent to Phases 12 and 13 (Figure 1-8). This work consisted of removal of contaminated material from pastures in an area of approximately 100 acres that had been flood irrigated with contaminated water from the Clark Fork River. This project area is located outside the Clark Fork River floodplain. Ongoing monitoring of vegetation establishment and weed control is being conducted in the Eastside Road and pastures. That monitoring work is not described within this report.

Remedial plans for the "Arrowstone Park" area (Figure 1-9) in the town of Deer Lodge, Montana are currently in the sampling and site characterization phase. The Arrowstone Park project area consists of a 1.2-mile river length and accompanying floodplain area. The start date for construction activities in the Arrowstone Park area is yet to be determined.

Remediation occurred in residential yards and the "Trestle" area of Deer Lodge, Montana in a portion of Phase14 (Figure 1-10). This work consisted of removal of contaminated material from residential yards and a recreational area along the Clark Fork River in the City of Deer Lodge. The work was completed in 2011 and approximately 10,000 cubic yards of contaminated soils were removed.

Remedial plans for Phases 15 and 16 (**Figure 1-11**) are currently in the design phase. These phases together consist of a 2.6-mile river length and an accompanying floodplain area of approximately 120 acres, which lie within the boundary of the Grant-Kohrs Ranch National Historic Site. Construction activities are anticipated to begin in these phases in 2018 and a total estimated volume of 400,000 cubic yards of contaminated material will be removed.

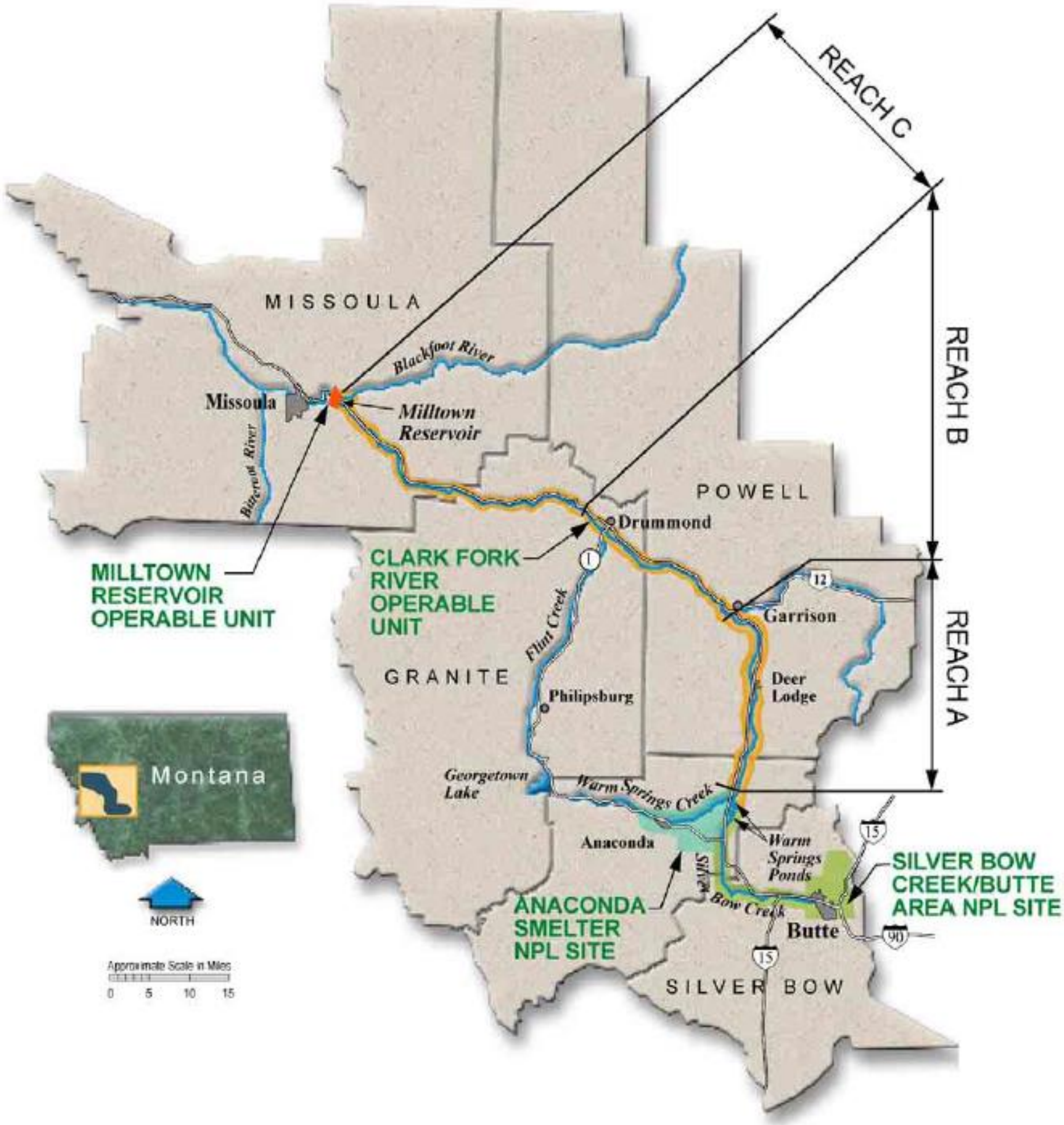

Figure 1-1. Remedial reaches of the Clark Fork River Operable Unit [USEPA, 2004].

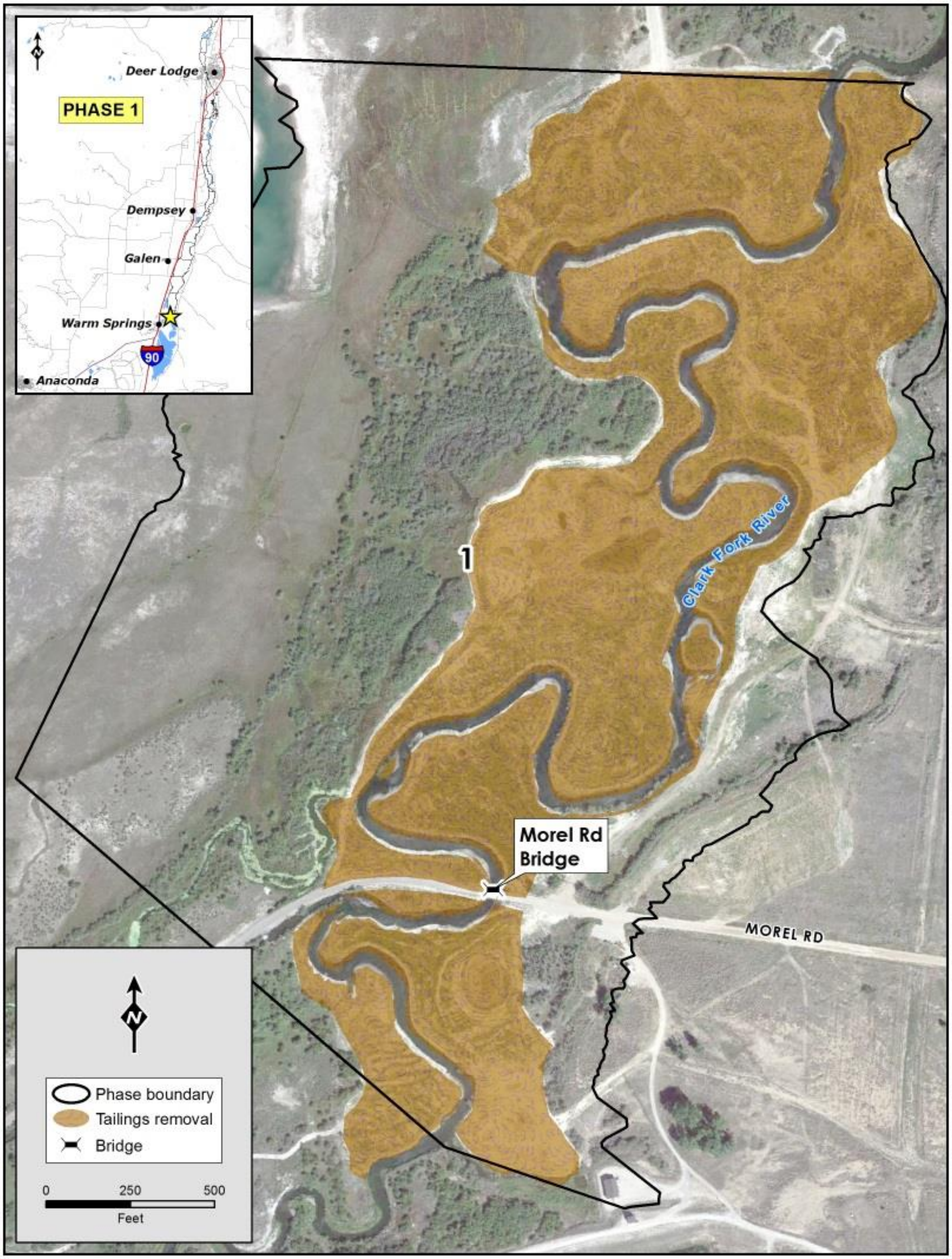

Figure 1-2. Phase 1 project area in the Clark Fork River Operable Unit.

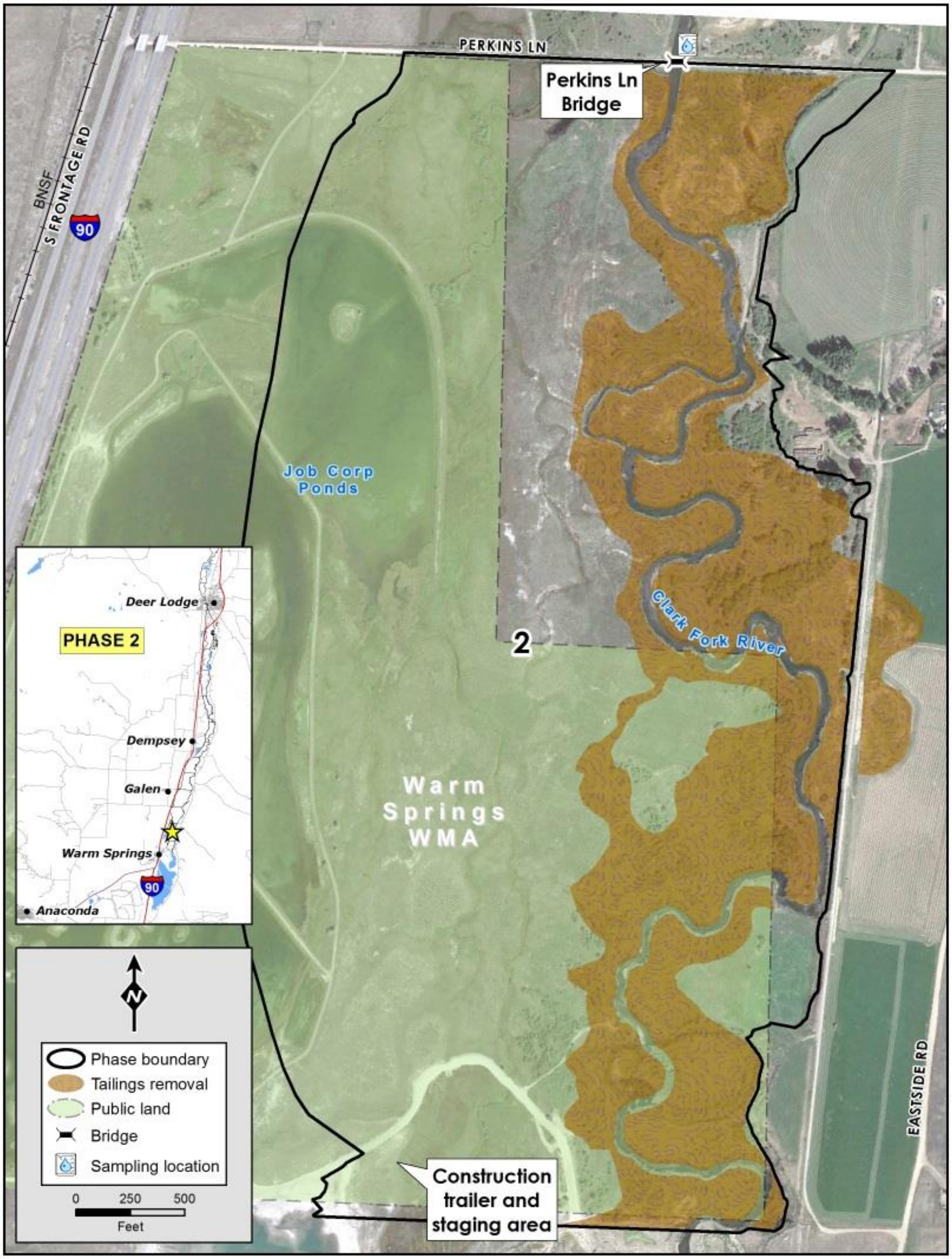

Figure 1-3. Phase 2 project area in the Clark Fork River Operable Unit.

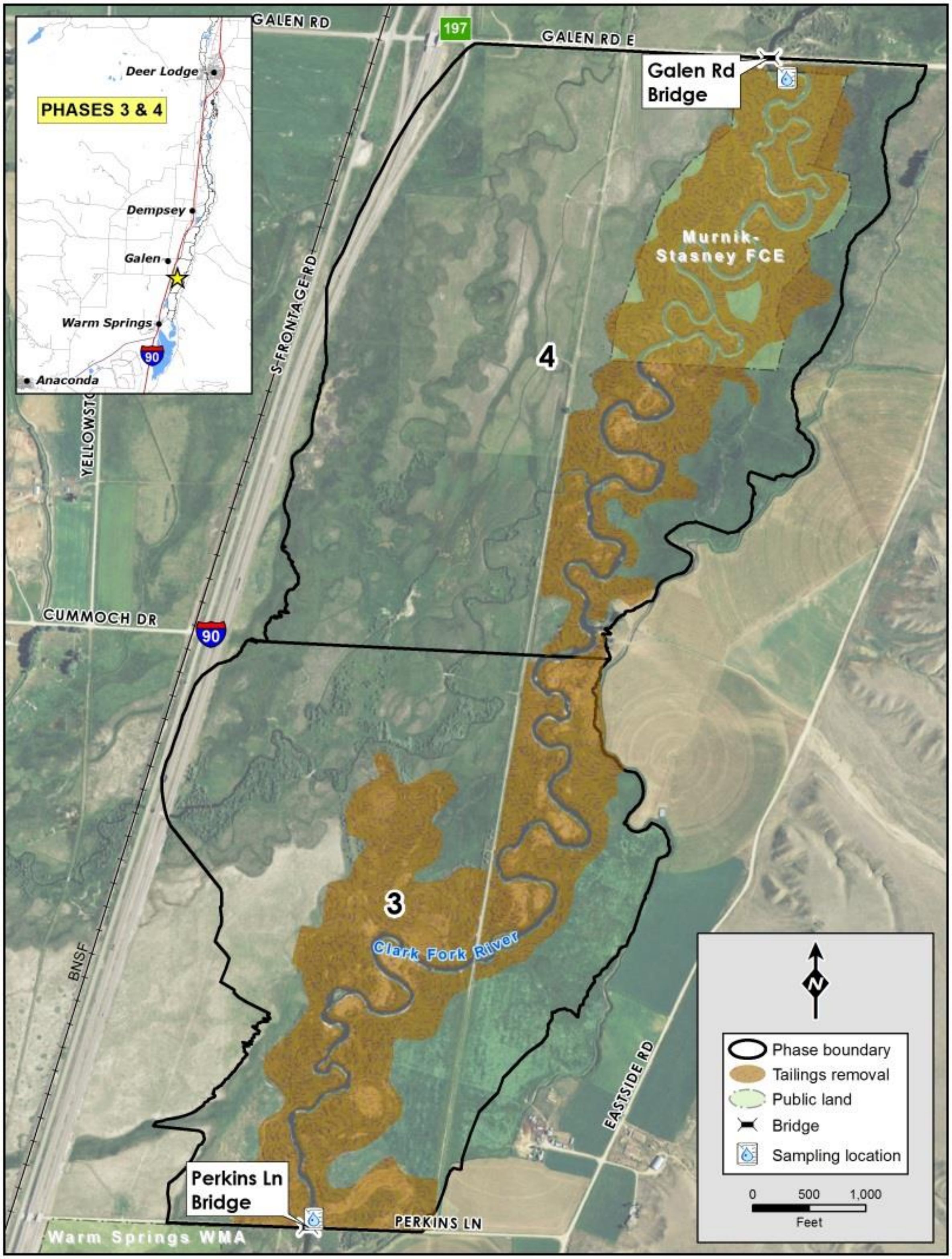

Figure 1-4. Phase 3 and 4 project areas in the Clark Fork River Operable Unit.

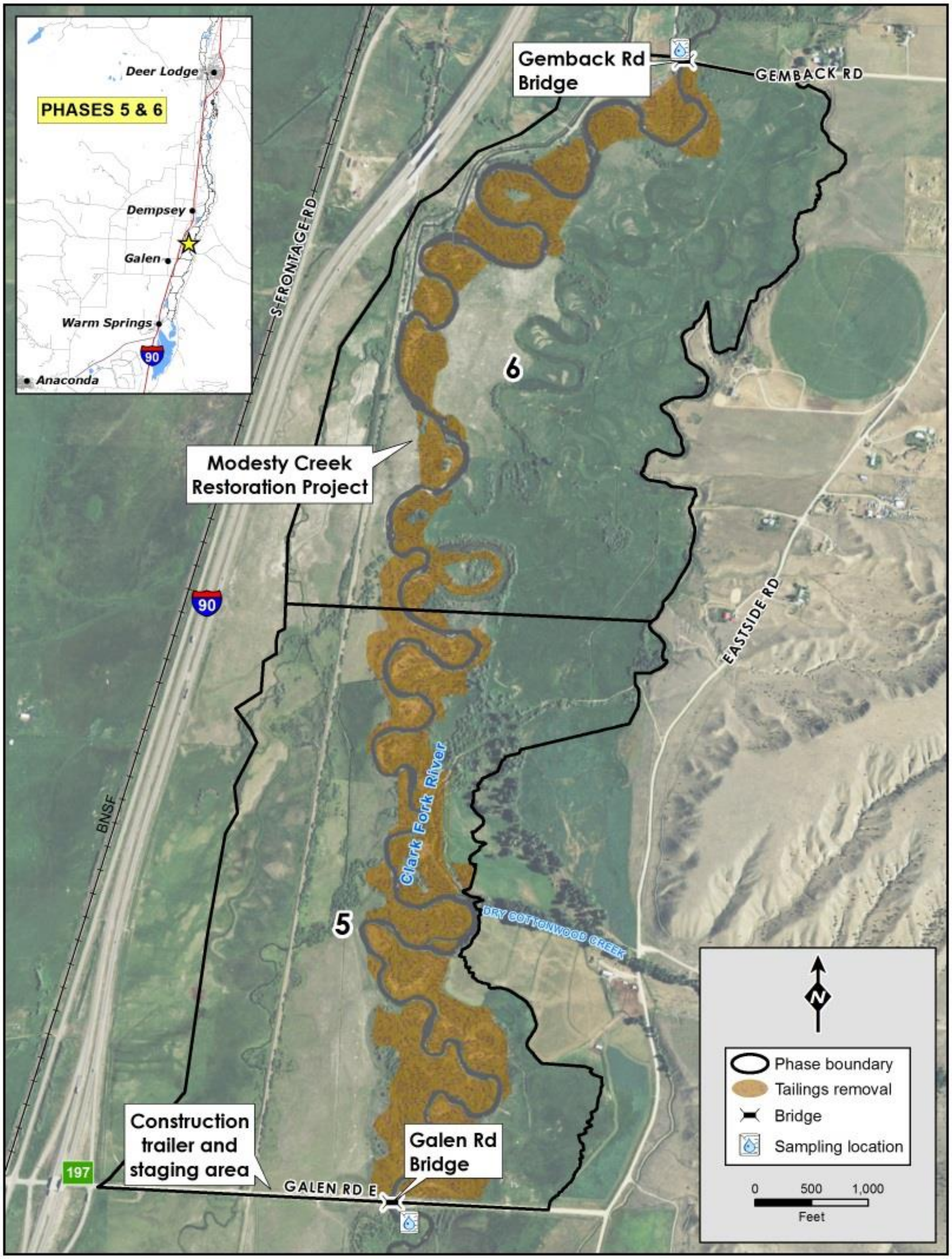

Figure 1-5. Phase 5 and 6 project areas in the Clark Fork River Operable Unit.

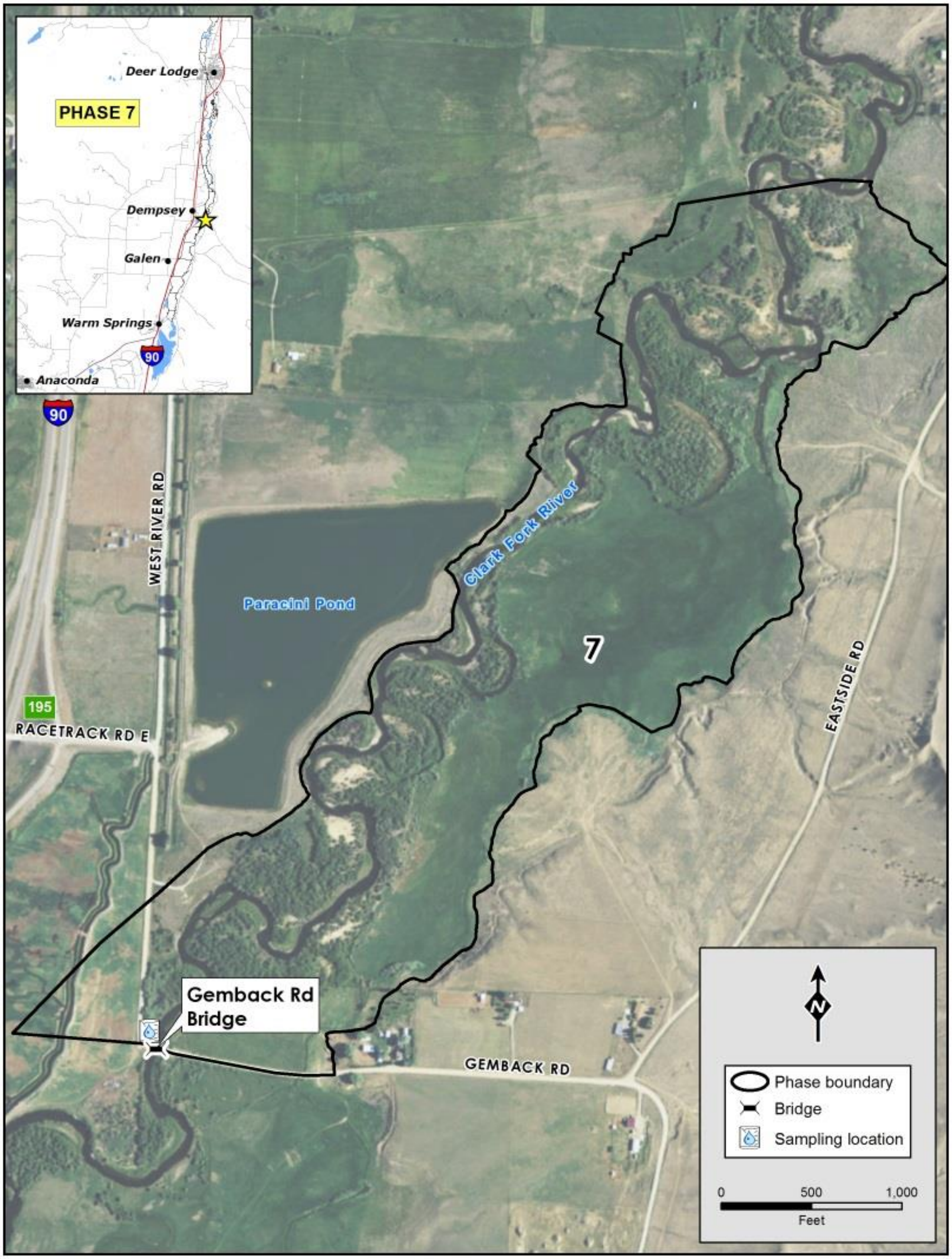

Figure 1-6. Phase 7 project area in the Clark Fork River Operable Unit.

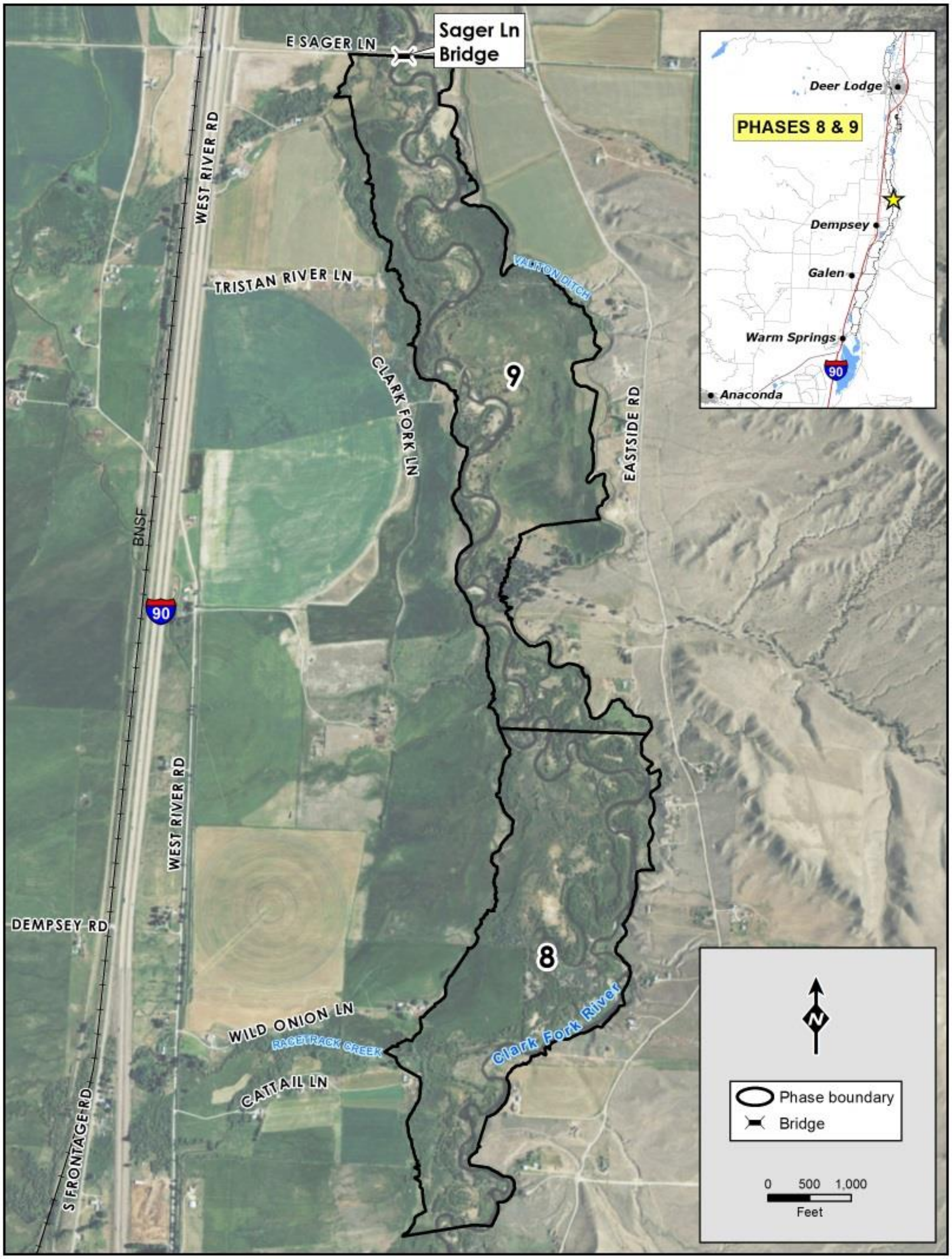

Figure 1-7. Phases 8 and 9 project areas in the Clark Fork River Operable Unit.

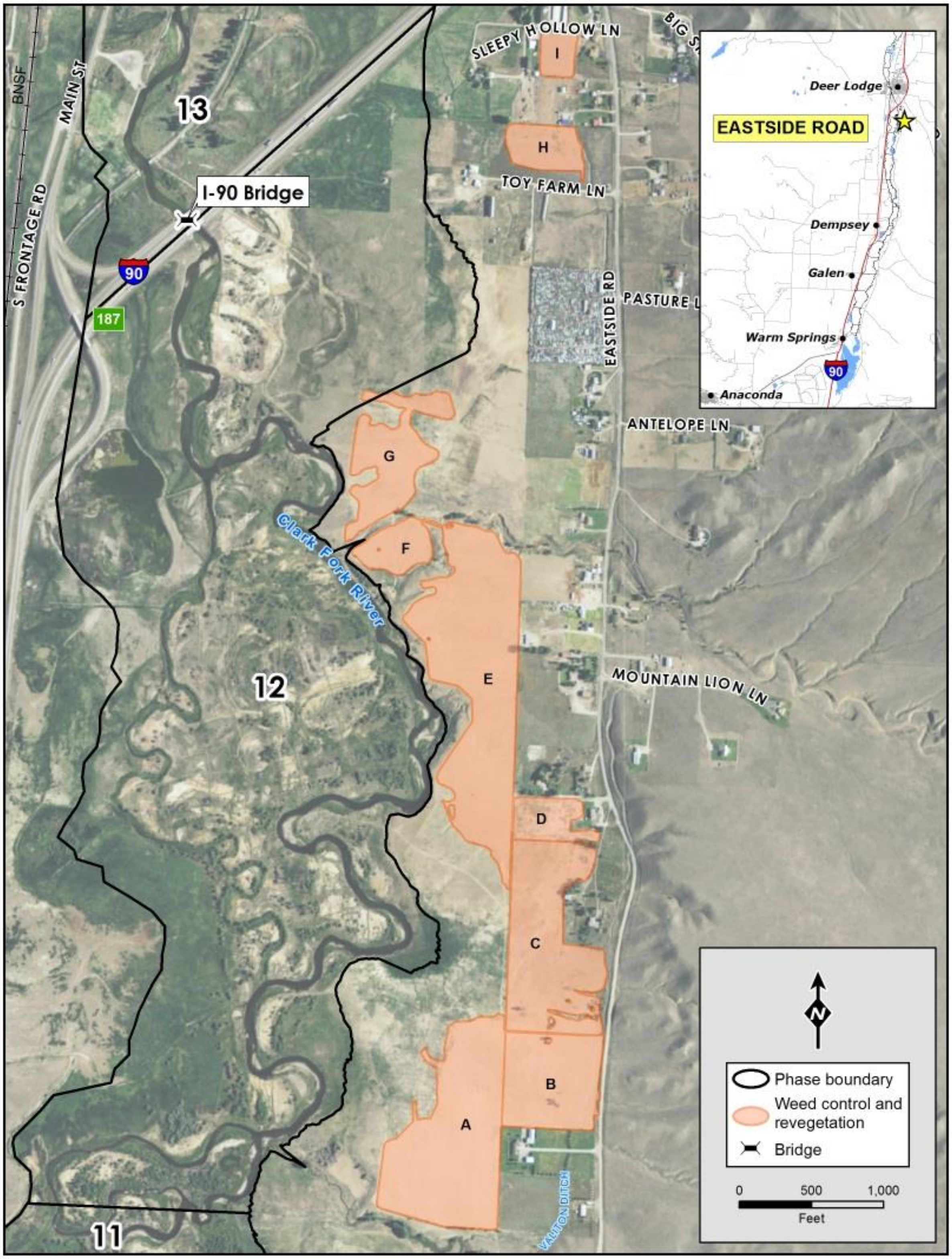

Figure 1-8. Eastside Road project area in the Clark Fork River Operable Unit.

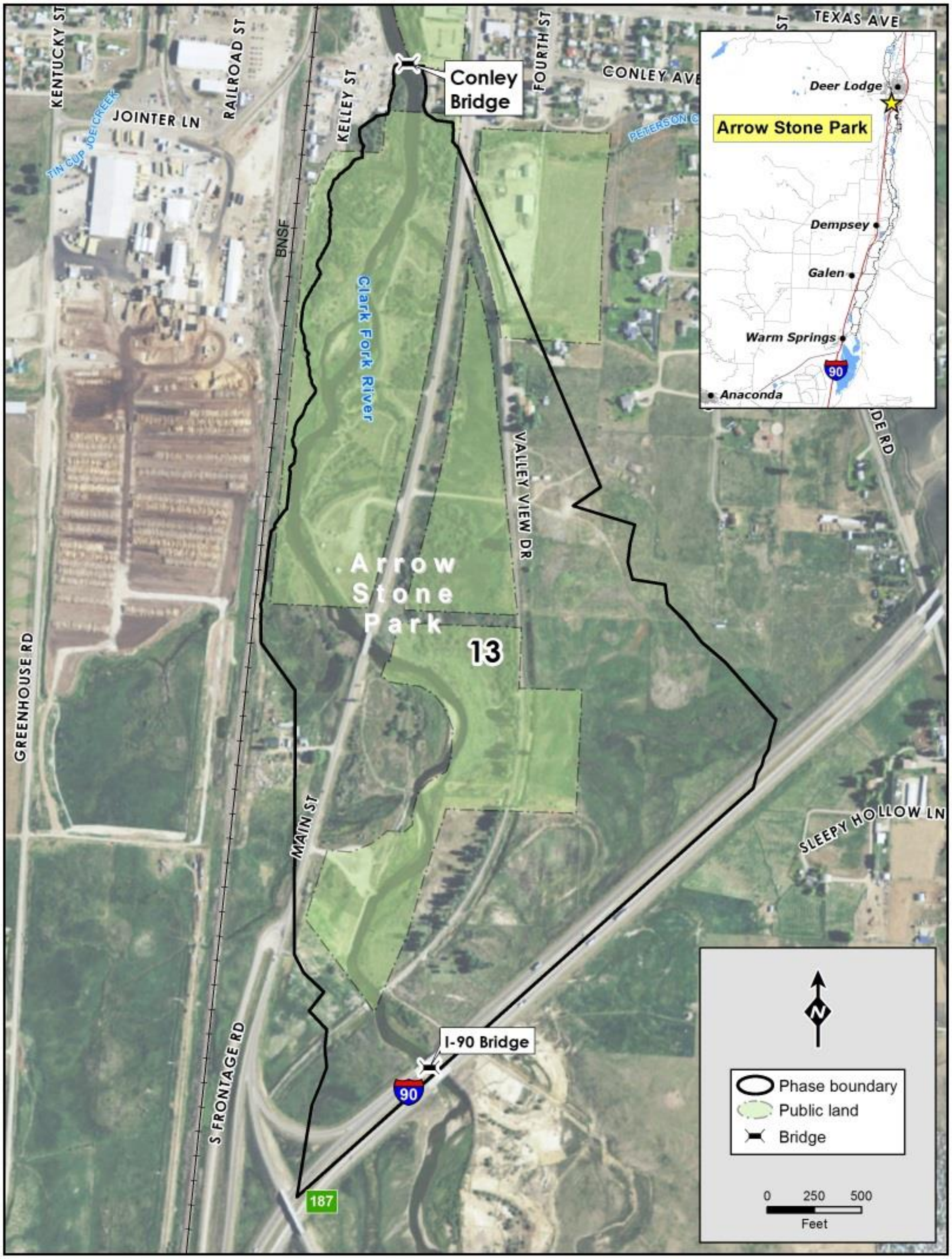

Figure 1-9. Arrowstone Park project area in the Clark Fork River Operable.

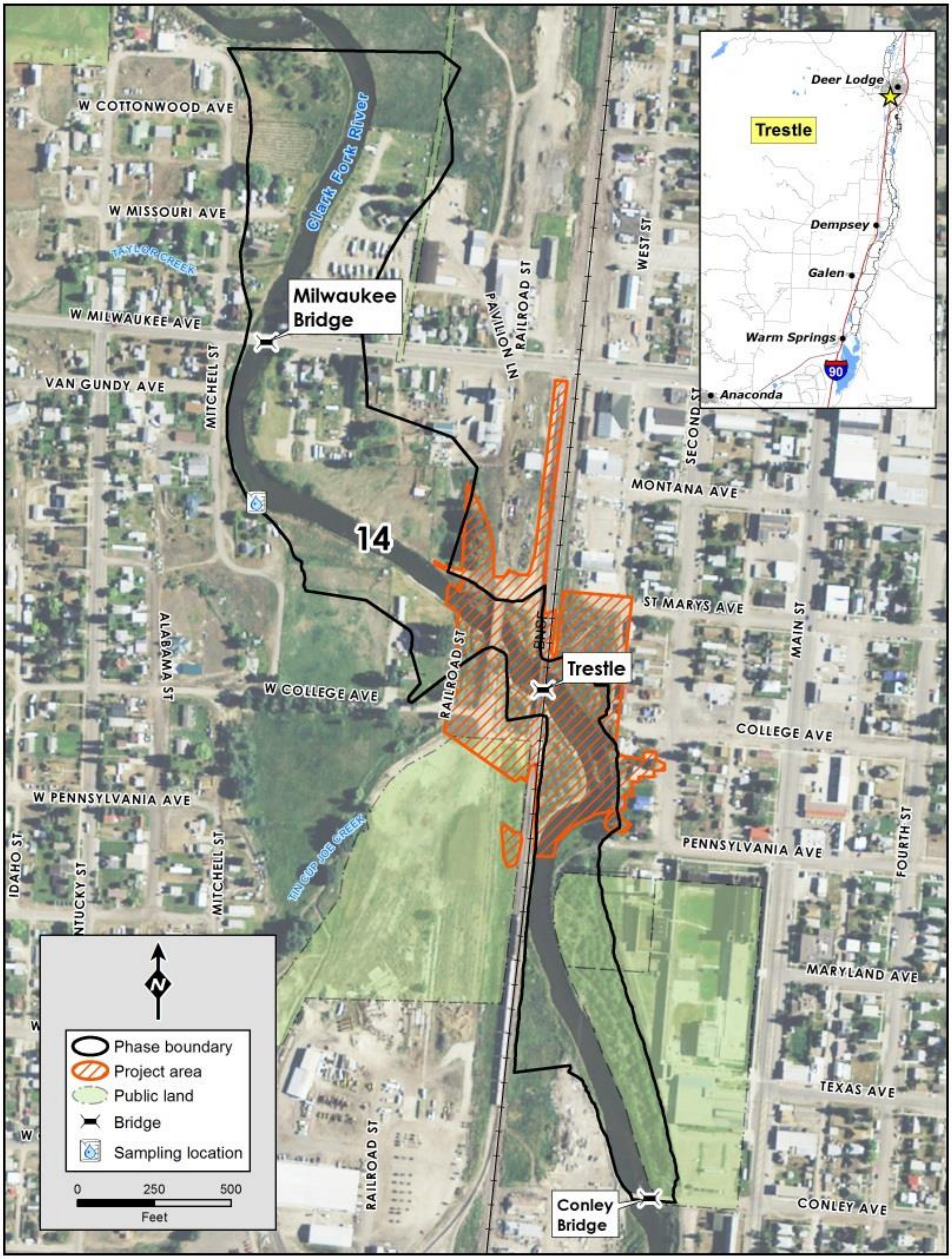

Figure 1-10. Trestle project area in the Clark Fork River Operable Unit.

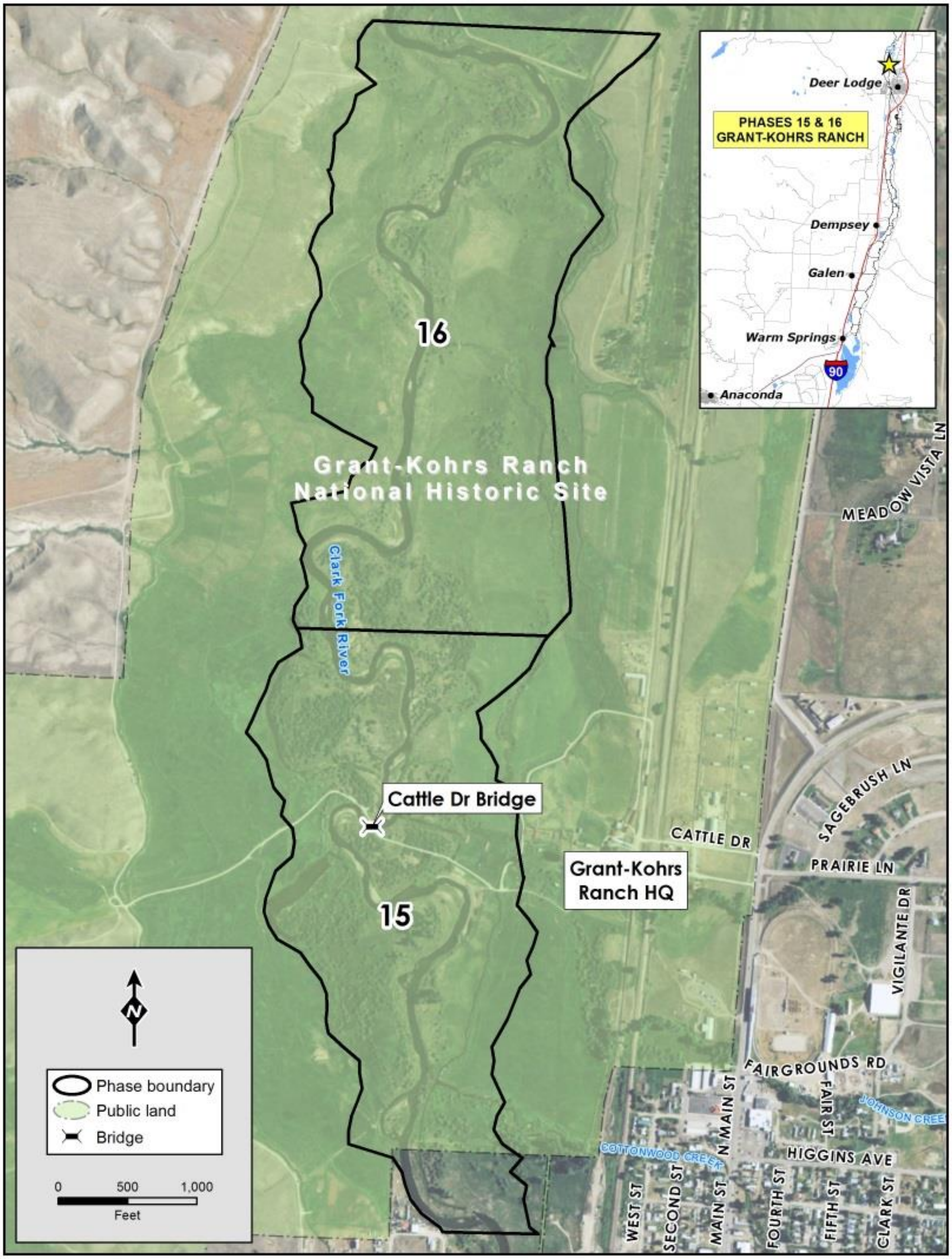

Figure 1-11. Phase 15 and 16 project areas in the Clark Fork River Operable Unit.

2.0 SURFACE WATER

2.1 INTRODUCTION

Performance goals were established in the CFROU ROD for surface water [USEPA, 2004]. The goal for surface water quality is for concentrations of all metal contaminants of concern (COCs) to be below the concentrations identified in the CFROU ROD (Table 2-1). The remedy for the Clark Fork River is expected to achieve these goals through the removal of contaminated floodplain soils (i.e., “slickens”), *in situ* (i.e., on site) treatment of floodplain soils with relatively low COC concentrations, and streambank stabilization. Additional removals of contaminated floodplain materials, proposed as part of remediation, may reduce arsenic concentrations as well. When the remediation activities are completed, surface water quality in the Clark Fork River is expected to fully support the growth and propagation of coldwater fishes (e.g., salmonids) and associated aquatic life. Surface waters will be monitored at specific locations along the Clark Fork River. Performance goals must be met at each location for the remedial actions to be considered successful.

This report evaluates progress toward attainment of surface water performance goals as defined in the CFROU ROD (Table 2-1). Water chemistry data were collected in 2017 to evaluate COC concentrations to make direct comparisons to relevant performance standards. In addition to COC concentrations, data are collected to describe other water quality constituents which influence the toxicity of metal contaminants or otherwise influence the ecology of the Clark Fork River. Other water quality constituents described include total suspended sediment, common ion, and nutrient concentrations and other physical properties of water (e.g., acidity).

Table 2-1. Remediation performance goals for surface water in the Clark Fork River Operable Unit [USEPA, 2004].

Contaminant of Concern	Performance Goal		
	Aquatic Life Standard[1]		Human Health or Drinking Water Standard (µg/L)
	Chronic (µg/L)	Acute (µg/L)	
Arsenic	150	340	10/18[2]
Cadmium	0.25	2	5
Copper[3]	9	13	1,300
Lead	3.2	81	15
Zinc	119	119	2,100

2.2 METHODS

The purpose of the surface water monitoring program is to collect data describing the temporal and spatial variation of metal and nutrient concentrations, and other physical properties of surface water in the CFROU. These data provide a long-term record of environmental conditions in the CFROU. As of 2017, eight years of CFROU surface water data (2010-2017) have been collected under this monitoring program. This long-term record provides a dataset to evaluate the effect of remediation on environmental conditions in the CFROU over time. Changes to the surface water monitoring program have occurred over time and a record of these changes is provided in the project sampling and analysis plan (SAP) [RESPEC, 2017a].

2.2.1 Monitoring Locations

Surface water was monitored at 15 CFROU sites in 2017 (Figure 2-1). The monitoring network included seven sites in the Clark Fork mainstem[4] and eight sites on tributary streams (Figure 2-1; Table 2-2).

2.2.1.1 Clark Fork River Mainstem

Each of the mainstem sample site locations were selected for a specific monitoring objective. The five mainstem Clark Fork River monitoring sites in Reach A (CFR-03A, CFR-07D, CFR-11F,

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[1] The aquatic life standards for cadmium, copper, lead, and zinc vary in relation to water hardness. The values displayed in this table correspond to a water hardness of 100 mg/L.

[2] The performance standard includes both the federal maximum contaminant level (MCL; 10 µg/L; dissolved concentration) and the state of Montana standard (18 µg/L; total recoverable concentration).

[3] Based on the federal ambient water quality criteria (USEPA [1986]; dissolved concentration).

[4] One mainstem site (Clark Fork River near Drummond; CFR-84F) was only monitored for a small set of analytes (i.e., field parameters, mercury, and methylmercury).

CFR-27H, CFR-34) were included to provide a detailed spatial representation of conditions in Reach A where the remedial work is occurring (Figure 2-1). Site CFR-34 was added to the monitoring network in 2015 to monitor upcoming remedial work planned in Phases 15 and 16 (**Figure 1-11**). The Reach C site (CFR-116A) represents conditions in Reach C at the downstream end of the Clark Fork River mainstem in the CFROU (Figure 2-1). Currently, no remedial actions are planned for Reach C. One mainstem site is located downstream from the Flint Creek tributary (CFR-84F) (Figure 2-1). Site CFR-84F is intended to assess the influence of the Flint Creek inflow which typically has elevated mercury concentrations [Langer et al., 2012; RESPEC, 2014; 2015; 2017b] on water quality in the mainstem.

2.2.1.2 Tributaries

Tributary site locations were selected to assess the significance of COC or nutrient loading from sources outside the CFROU. Each tributary has one sample site located near the tributary confluence with the Clark Fork River. Mill-Willow Creek and Silver Bow Creek also have additional sites located further upstream in each tributary (Figure 2-1).

2.2.1.2.1 Silver Bow Creek

Silver Bow Creek is the upstream-most tributary of the Clark Fork River. Silver Bow Creek historically was the primary source of COCs to the Clark Fork River [DEQ and USEPA, 1995] but it has undergone extensive remediation since 1998 and COC concentrations are reduced compared to historic levels [Sando et al., 2014; RESPEC, 2017c]. All streamflow from Silver Bow Creek is captured by the Warm Springs Ponds and treated to reduce metal loading to the Clark Fork River (see: www.cfrtac.org).

Three sample sites are included on Silver Bow Creek; Silver Bow Creek at Frontage Road (SS-19) located immediately above the Warm Springs Ponds; Silver Bow Creek at the Pond 2 outfall (SBC-P2) located immediately below the primary spillway of the Warm Springs Ponds, and Silver Bow Creek at Warm Springs (SS-25) located immediately below the confluence of Silver Bow Creek and Mill-Willow Creek (Figure 2-1). During some sample periods, site SS-19 was sampled as part of the Streamside Tailings Operable Unit monitoring program. Sample collection methods for site SS-19 are described in the SSTOU sampling and analysis plan [RESPEC, 2017d].

2.2.1.2.2 Mill-Willow Creek

Mill-Willow Creek is a tributary to Silver Bow Creek and flows into Silver Bow Creek immediately downstream from the Warm Springs Pond outfall (Figure 2-1). Historically, Mill and Willow Creeks joined Silver Bow Creek upstream from the Warm Springs Ponds. However, because contaminant levels in Mill and Willow Creeks were low relative to Silver Bow Creek, streamflows from Mill and Willow Creek were routed around the Warm Springs Pond system through a designed channel commonly referred to as the “Mill-Willow Bypass”. The Mill-Willow Bypass was remediated between 1990 and 1995 to remove tailings and contaminated soils along the stream channel and floodplain and to reduce toxic discharges to Silver Bow Creek and the upper Clark Fork River (see: www.cfrtac.org).

Two sample sites are in Mill-Willow Creek: MCWC-MWB and MWB-SBC (Figure 2-1). Site MCWC-MWB is located at the upstream end of the Mill-Willow Bypass to demonstrate background water quality conditions in Mill-Willow Creek. Site MWB-SBC is located near the Silver Bow Creek confluence. Increases in contaminant concentrations between MCWC-MWB and MWB-SBC suggest that contaminant loading is occurring in the Mill-Willow Bypass reach of Mill-Willow Creek.

2.2.1.2.3 Warm Springs Creek

The Clark Fork River mainstem begins at the confluence of Silver Bow Creek and Warm Springs Creek (Figure 2-1). Warm Springs Creek is a major tributary to the Clark Fork River in Reach A. Warm Springs Creek typically has relatively low nutrient concentrations and relatively cool streamflows. Water chemistry in Warm Springs Creek is monitored at site WSC-SBC (Figure 2-1).

2.2.1.2.4 Little Blackfoot River

The Little Blackfoot River is a major tributary to the Clark Fork River. The Little Blackfoot River and Clark Fork River confluence is located at the boundary between CFROU Reach A and Reach B (Figure 2-1). Water quality and quantity in the Little Blackfoot River may be influenced by a variety of land uses including agriculture and irrigation in lower portions of the watershed and abandoned mining in headwater portions of the watershed [Montana Engineer's Office, 1959; Lyden, 1987; Ingman, 2002; DEQ and USEPA, 2011; 2014]. Monitoring in the Little Blackfoot River occurred at LBR-CFR-02 (Figure 2-1).

2.2.1.2.5 Flint Creek

Flint Creek enters the Clark Fork River near the boundary between Reach B and Reach C (Figure 2-1). Flint Creek is a major source of mercury to the Clark Fork River [Langner et al., 2012; RESPEC, 2014; 2015; 2017b]. Site FC-CFR monitors water chemistry in Flint Creek (Figure 2-1).

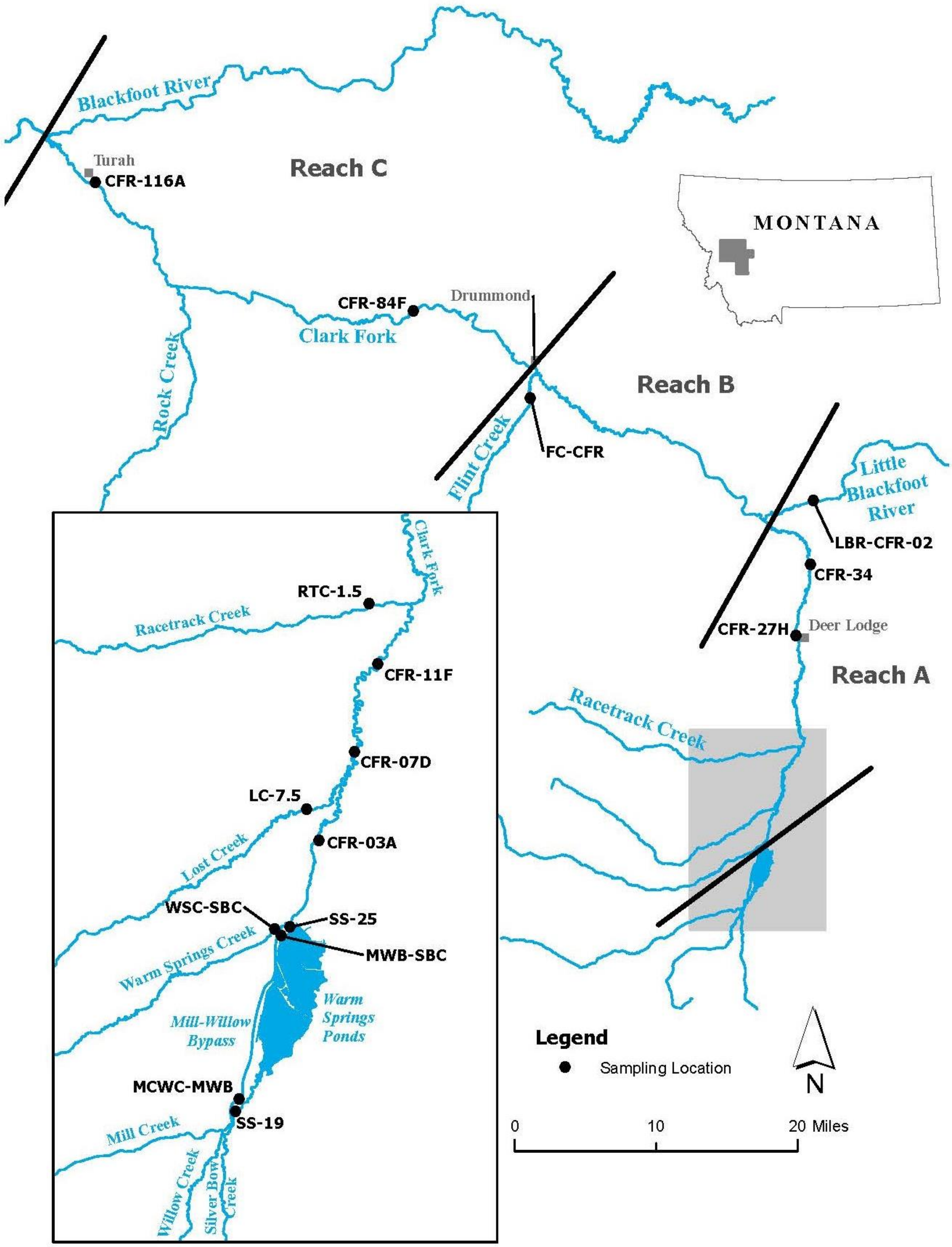

Figure 2-1. Surface water sampling locations in the Clark Fork River Operable Unit.

Table 2-2. Surface water sampling locations in the Clark Fork River Operable Unit. Streamflows were measured at all sites which did not a have co-located U.S. Geological Survey (USGS) streamflow gage.

Site ID	Site Location	Co-located USGS Streamflow Gage	Location (GPS coordinates, NAD 83)	
			Latitude	Longitude
Mainstem Sites				
CFR-03A	Clark Fork River near Galen	12323800	46.20877	-112.76740
CFR-07D	Clark Fork River at Galen Road	none	46.23725	-112.75302
CFR-11F	Clark Fork River at Gemback Road	none	46.26520	-112.74430
CFR-27H	Clark Fork River at Deer Lodge	12324200	46.39796	-112.74283
CFR-34	Clark Fork River at Williams-Tavenner Bridge	none	46.47119	-112.72492
CFR-84F	Clark Fork near Drummond	12331800	46.71204	-113.33137
CFR-116A	Clark Fork at Turah	12334550	46.82646	-113.81424
Tributary Sites				
SS-19[5]	Silver Bow Creek at Frontage Road	none	46.12247	-112.80032
SBC-P2	Silver Bow Creek at Pond 2 outfall	none	46.17840	-112.78190
SS-25	Silver Bow Creek at Warm Springs	12323750	46.18123	-112.77917
MCWC-MWB	Mill-Willow Creek at Frontage Road	none	46.12649	-112.79876
MWB-SBC	Mill-Willow Bypass near mouth	none	46.17839	-112.78270
WSC-SBC	Warm Springs Creek near mouth	12323770	46.18041	-112.78592
LBR-CFR-02[6]	Little Blackfoot River at Beck Hill Road	none	46.53710	-112.72443
FC-CFR	Flint Creek near mouth	12331500	46.62891	-113.15151

2.2.2 Monitoring Schedule

At least one monitoring event occurred during each calendar quarter of 2017. Each quarterly monitoring event occurred near the end of each quarter. The first monitoring event (Q1) occurred in the late winter from March 6-7. Three monitoring events were conducted in the second quarter (Q2) to approximate the rising (Q2-Rising), peak (Q2-Peak), and falling (Q2-Falling) portions of the spring runoff hydrograph. The Q2 monitoring events were conducted on May 15-16 (Q2-Rising), June 7-8 (Q2-Peak), and June 27-28 (Q2-Falling). The late summer (Q3) monitoring event occurred from September 5-6. The late fall (Q4) monitoring event occurred from November 27-28. During some monitoring periods, SS-19 was sampled on the following day after sampling in the other CFROU sites was completed.

[5] In 2015, site SS-19 was sampled under the Streamside Tailings Operable Unit (SSTOU) monitoring program four times per year.

[6] Site LBR-CFR (GPS Location: 46.51964, -112.79312; co-located USGS gage: 12324590) was replaced by site LBR-CFR-02 in 2014.

2.2.3 Monitoring Parameters

Surface water samples were analyzed for the parameters and analytes listed in Table 2-3. Parameters and analytes were the same at all sites except for Sites FC-CFR and CFR-84F. At site FC-CFR, mercury and methylmercury concentrations were analyzed in addition to all other analytes. At site CFR-84F, a surface water sample was collected but only analyzed for mercury and methylmercury concentrations. All parameters listed in Table 2-3 were monitored as well as some additional parameters as described in RESPEC [2017a].

Eight monitoring stations in the DEQ Clark Fork River monitoring network were co-located with active U.S. Geological Survey (USGS) streamflow gauging stations (Table 2-2). U.S. Geological Survey streamflow records were accessed and included in this report. Streamflows at monitoring stations without co-located U.S. Geological Survey gages were measured manually.

Table 2-3. Sampling parameters and analytes for surface water monitoring of the Clark Fork River Operable Unit.

Parameter	Analytes
Metal concentrations (total recoverable and dissolved)[7]	Arsenic, cadmium, copper, lead, zinc, mercury, methylmercury
Nutrient concentrations	Nitrogen (total nitrogen, nitrate plus nitrite, ammonia[8]), and phosphorus (total)
Common ion concentrations (total)	Sulfate, chloride, alkalinity, bicarbonate, magnesium, potassium, sodium
Field parameters	Total suspended sediment (TSS) concentration, hardness, water temperature, pH, specific conductivity, dissolved oxygen (DO) concentrations, turbidity

2.2.4 Sample Collection and Analysis

Sample collection, analysis, and quality assurance procedures were described in the quality assurance project plan [Atkins, 2013]. Methods generally followed standard operating procedures (SOPs) developed for the Clark Fork River [AR, 1992]. Field sampling procedures were in accordance with DEQ [2012a] and followed "clean hands/dirty hands" procedures to minimize sample contamination as described in USGS [2006][9]. Composited surface water samples were collected using width-depth integration according to methods described in USGS [2006]. When

[7] At CFR-84F, no nutrient or metal concentrations were measured except mercury and methylmercury. At FC-CFR, mercury and methylmercury were measured in addition to all other analytes.

[8] Ammonia concentrations were only measured in the Silver Bow Creek sites in 2017.

[9] We deviated from the USGS [2006] protocols to minimize sample contamination (Section 4.0.2) in two regards. First, we did not collect samples sequentially in the order of least to greatest potential for contamination. Second, samples were processed outside the sampling vehicles, rather than within an enclosed space.

streamflows were high and samples could not be safely collected by wading, samples were collected with the aid of a crane mounted D-95 sampler operated from road bridges. Field parameters (water temperature, pH, dissolved oxygen concentration, and conductivity) were measured during each monitoring event with a field multimeter (YSI Professional Plus or YSI 556). Turbidity was measured with a field turbidity meter (Hach Model 2100P Portable Turbidimeter). Streamflows were measured using a portable electromagnetic streamflow meter (Marsh-McBirney Flo-Mate 2000). Calibration methods for field meters, data recording and handling methods, and quality assurance and quality control procedures are described in the quality assurance project plan [Atkins, 2013]. Samples were analyzed by Energy Laboratories (Helena, Montana). Requested laboratory analysis procedures for each analyte are presented in Table 2-4.

Table 2-4. Analytes, methods, and reporting limits for surface water samples in the Clark Fork River Operable Unit. All samples were analyzed by Energy Laboratories in Helena, Montana.

Analyte	Requested Method	Requested Reporting Limit (mg/L)[10]	Holding Time (days)	Bottle	Preservative
Water Samples - Physical Properties and Inorganics					
Solids, Total Suspended (at 105C)	A 2540 D	1	7	1 L HDPE	4 ± 2 C
Alkalinity, Total (as CaCO3)	A 2320 B	4	14	500 mL HDPE	
Alkalinity, Bicarbonate (as HCO3)	A 2320 B	4	14		
Chloride	EPA 300.0	1	28		
Sulfate	EPA 300.0	1	28		
Hardness (as CaCO3)	A 2340 B	1	180		
Water Samples – Nutrients					
Nitrogen, Ammonia (as N)	EPA 350.1	0.05	28	250 mL HDPE	4 ± 2 C
Nitrogen, Nitrate-Nitrite (as N)	EPA 353.2	0.02			H2SO4 to pH<2, 4 ± 2 C
Nitrogen, Total	A 4500 N-C	0.05	30		4 ± 2 C
Phosphorus, Total	EPA 365.1	0.003	28		H2SO4 to pH<2, 4 ± 2 °C
Water Samples - Dissolved Metals (0.45 µm filtered)					
Arsenic	EPA 200.8	0.001	180	250 mL HDPE	HNO3 to pH <2
Cadmium	EPA 200.8	0.00003			
Copper	EPA 200.8	0.001			
Lead	EPA 200.8	0.0003			
Zinc	EPA 200.8	0.008			
Water Samples - Total Recoverable Metals					
Total Recoverable Metals Digestion	EPA 200.2	-	-	-	-
Arsenic	EPA 200.8	0.001	180	250 mL HDPE	HNO3 to pH <2
Cadmium	EPA 200.8	0.00003			
Calcium	EPA 200.7	1			

[10] Requested reporting limits are either the required reporting limit of DEQ [2012a] or DEQ [2014], or the lowest reporting limit previously provided by the analytical laboratory, whichever is lower.

Analyte	Requested Method	Requested Reporting Limit (mg/L)[10]	Holding Time (days)	Bottle	Preservative
Copper	EPA 200.8	0.001			
Lead	EPA 200.8	0.0003			
Magnesium	EPA 200.7	1			
Potassium	EPA 200.7	1			
Sodium	EPA 200.7	1			
Zinc	EPA 200.8	0.008			
Mercury	EPA 245.1	0.000005	28	250 mL HDPE	HNO3 to pH <2,
Methylmercury	EPA 1630	0.05 ng/L	28	250 mL FLPE	HCl to pH <2,

2.2.5 Data Analysis

Data analysis approaches included evaluation of remedial performance goal exceedances (for COCs) or relevant regulatory standards (for non-COC constituents) and evaluation of spatial and temporal trends.

Exceedances were assessed by comparing constituent concentrations to the relevant performance goal or regulatory standard. For some COCs and for ammonia concentrations, the relevant goal or standard is based on site- and time-specific conditions (e.g., hardness-based standards; DEQ [2017] which were measured concomitantly with each sample collected. Some performance goals and regulatory standards assume that the measured constituent concentration will be consistent over a specific period. For example, the chronic aquatic life standard is typically based on 96-hour mean concentrations [DEQ, 2017]. However, in this monitoring program analyte concentrations were measured at a specific point in time and mean concentrations over time are unknown. Therefore, assessments of performance goal or regulatory standard exceedances assume that the measured concentration was representative of the required period as relates to each specific goal or standard. Boxplots were created to summarize data collected in this monitoring year and to evaluate spatial trends. Statistics summarized in each boxplot include the median (midline of each box), quartiles (ends of each box), outlier extent (whiskers which extend 1.5 times the interquartile range or to the most extreme observation if no observations extend beyond 1.5 times the interquartile range), and outliers (circles above or below the whiskers which are any observations more than 1.5 times the interquartile range). Boxplots were only generated for data with more than five observations. Temporal trends were also evaluated (for COCs) plotting all observations in scatterplots at each site for the period of record.

Scatterplots were created to summarize all data collected at each monitoring site sense monitoring began in 2010 and to evaluate evidence of monotonic (increasing or decreasing) trends. A substantial portion of the constituent concentrations were below analytical reporting limits and therefore the precise concentration was unknown. In those cases, values were substituted at half the reporting limit to generate scatterplots and boxplots and to calculate summary statistics (e.g., medians).

2.2.6 Data Validation

Data quality objectives (DQOs) were established in the CFROU monitoring project quality assurance project plan (QAPP) for data "representativeness", "comparability", "completeness", "sensitivity", "precision", "bias", and "accuracy" [Atkins, 2013]. Methods for field and laboratory quality assurance and quality control (QA/QC) procedures are also described in detail in the project QAPP. A completed QA/QC checklist, summary tables of field duplicate and field blank results, and assessments of data quality objectives are included in Appendix A.

2.3 RESULTS

2.3.1 Streamflows

Streamflows in 2017 are depicted for each CFROU site with a co-located USGS streamflow gage: Silver Bow Creek at Warm Springs (USGS 12323750) (Figure 2-2), Warm Springs Creek at Warm Springs (USGS 12323770) (Figure 2-3), Clark Fork River near Galen (USGS 12323800) (Figure 2-4), Clark Fork River at Deer Lodge (USGS 12324200) (Figure 2-5), Flint Creek (USGS 12331500) (Figure 2-6), Clark Fork River near Drummond (USGS 12331800) (Figure 2-7), and Clark Fork River at Turah (USGS 12334550) (Figure 2-8).

Generally, streamflows in 2017 tracked long-term trends at most sites. At most sites, spring runoff was similar to the long-term trend in duration and magnitude. At some sites, particularly in the mainstem, peak flows were relatively high (e.g., approximately 10,000 cubic feet per second [cfs] at Turah; Figure 2-8) compared to the long-term. Some sites also had brief elevated streamflow increases in flows in mid- (February) and late-winter (March). At some sites (Silver Bow Creek at Warm Springs (Figure 2-2), Clark Fork River at Deer Lodge (Figure 2-5), and Flint Creek (Figure 2-6), summer streamflows were low compared to the long-term median especially in Flint Creek which dipped to less than 8 cfs on August 8-9, 2017.

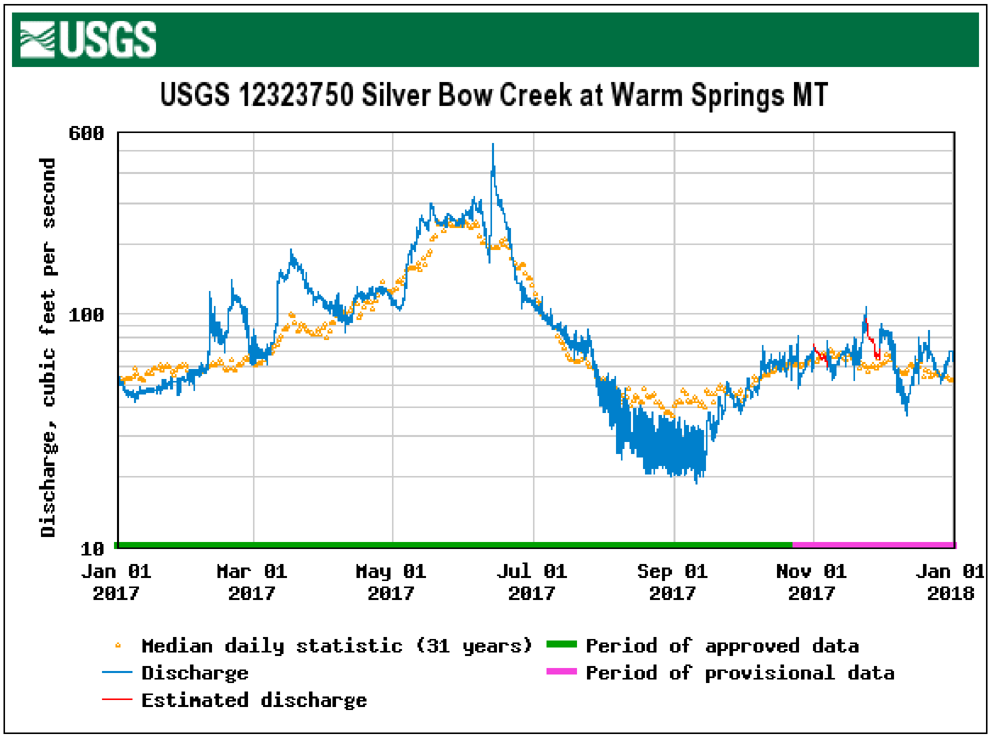

Figure 2-2. Hydrograph for Silver Bow Creek at Warm Springs, 2017.

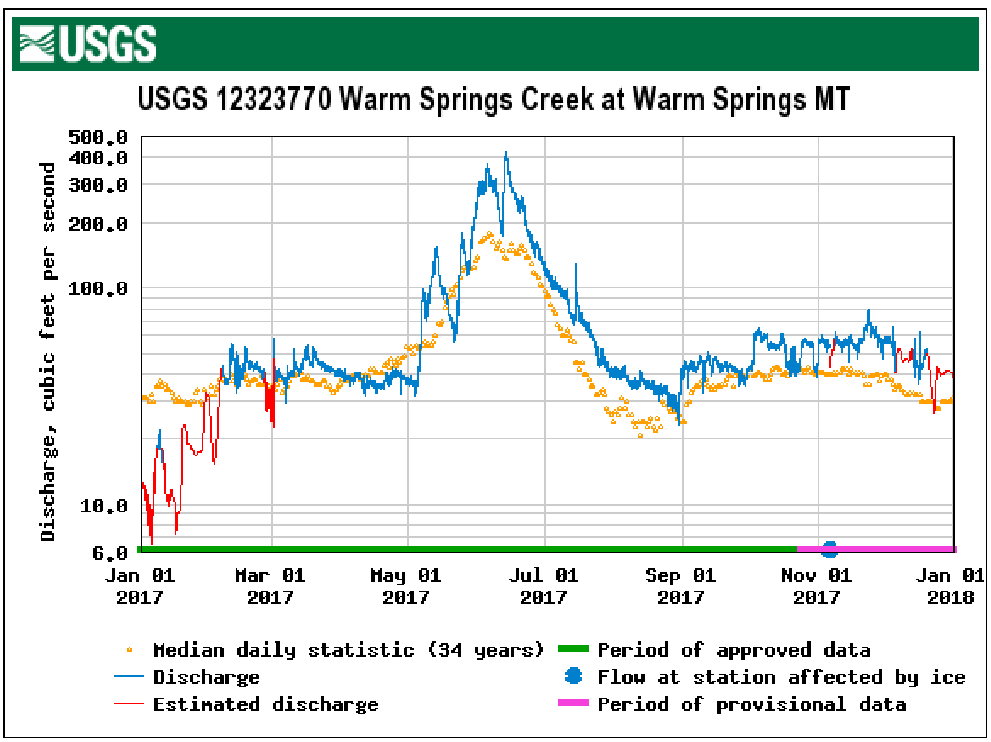

Figure 2-3. Hydrograph for Warm Springs Creek at Warm Springs, 2017.

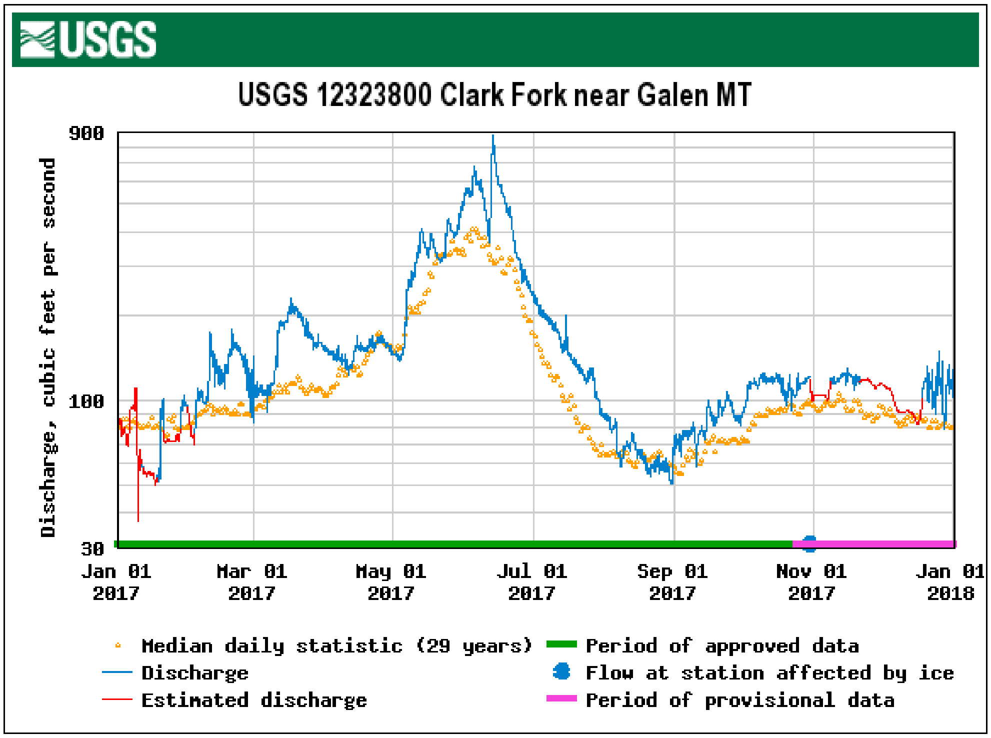

Figure 2-4. Hydrograph for Clark Fork River near Galen, 2017.

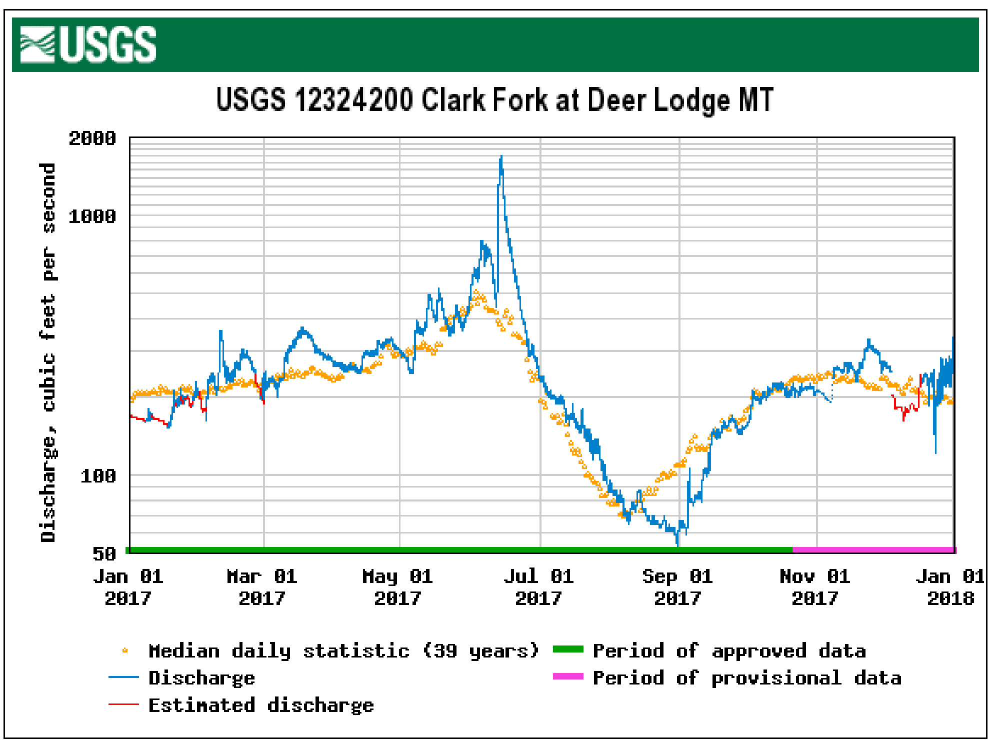

Figure 2-5. Hydrograph for Clark Fork River at Deer Lodge, 2017.

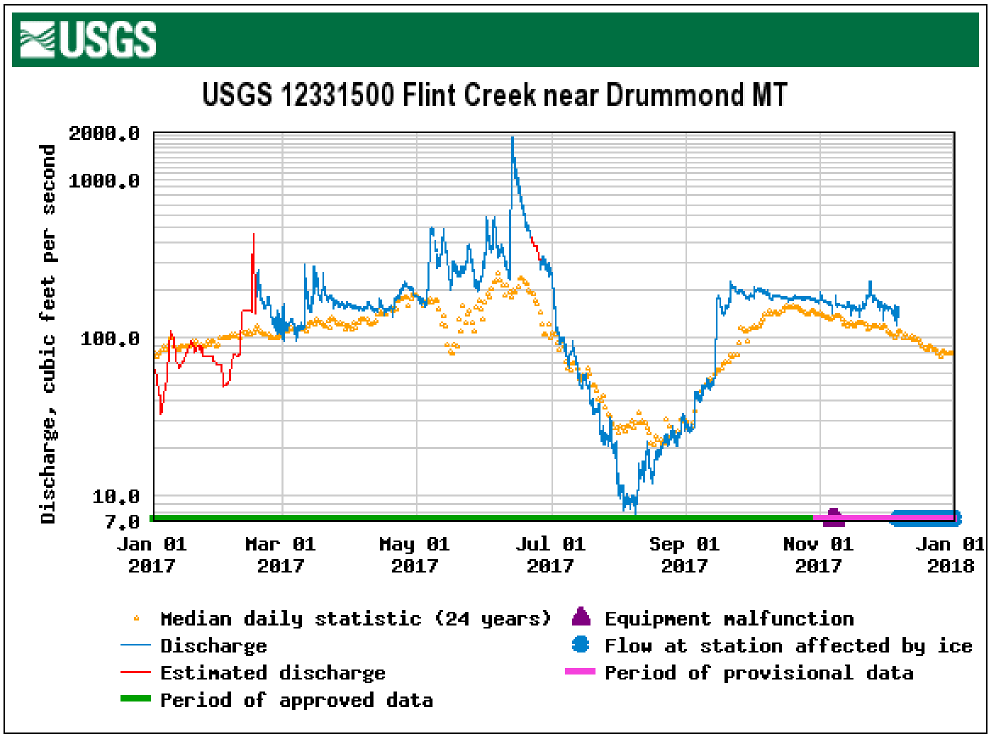

Figure 2-6. Hydrograph for Flint Creek, 2017.

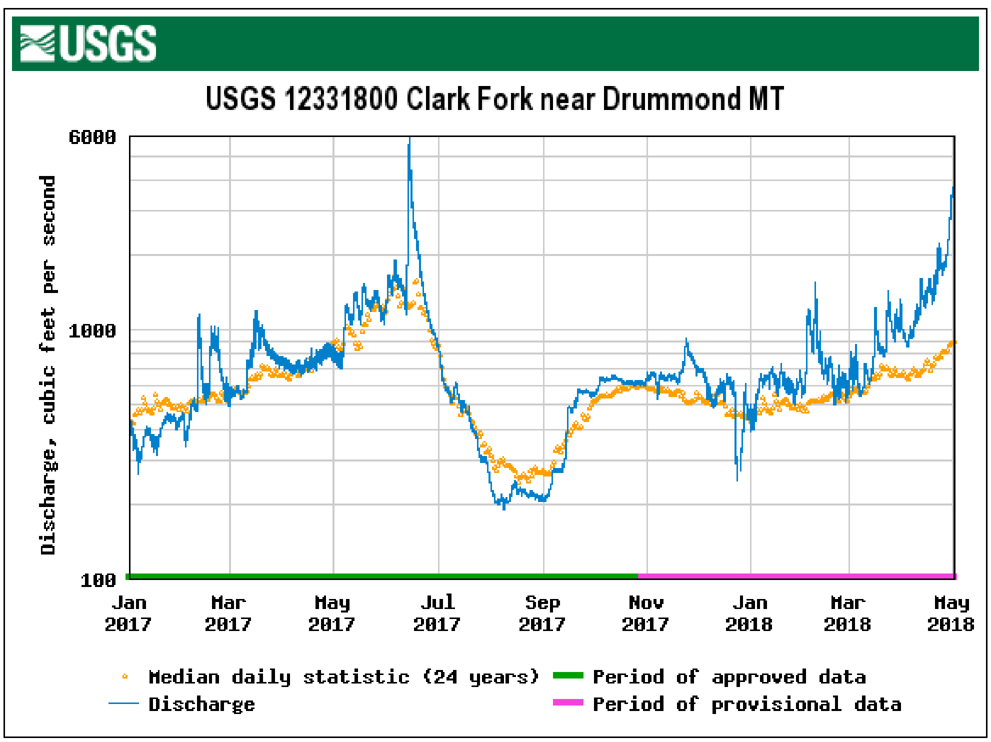

Figure 2-7. Hydrograph for Clark Fork River near Drummond, 2017.

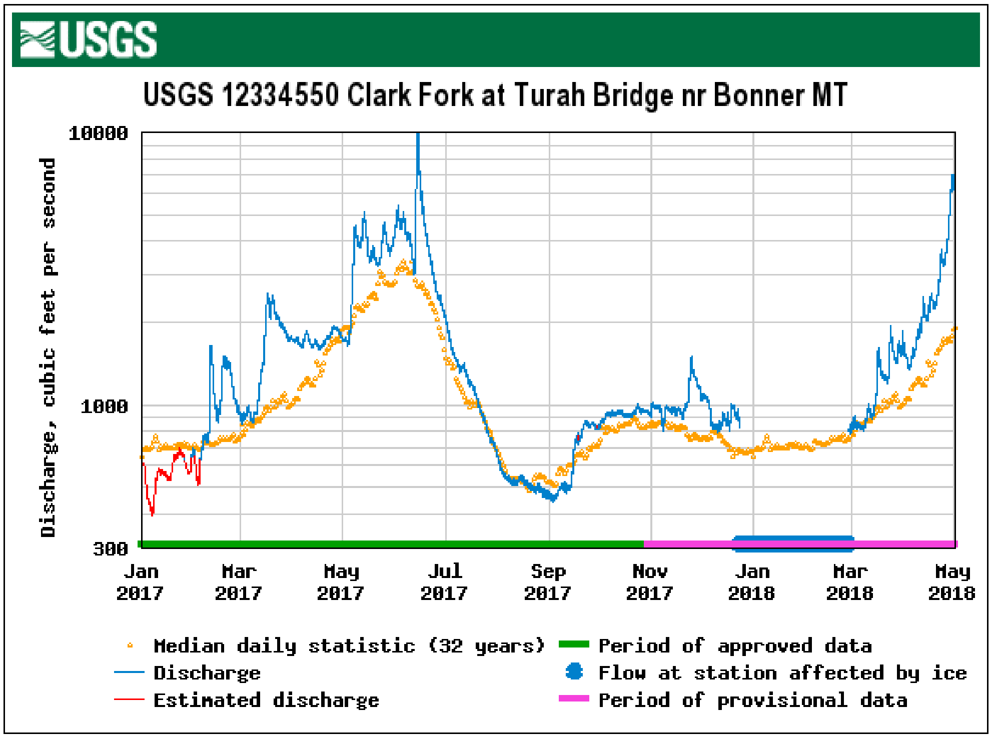

Figure 2-8. Hydrograph for Clark Fork at Turah Bridge, 2017.

2.3.2 Field Parameters

2.3.2.1 Water Temperature

At the time samples were collected in 2017, Clark Fork River mainstem water temperatures ranged from 0-18.1°C (Figure 2-9). The highest maximum water temperatures occurred in Reach A during the Q2-Falling or Q3 sample periods.

Water temperatures in the Clark Fork River tributaries ranged from 0-20.5 °C (Figure 2-10). Comparisons of water temperatures among tributaries are confounded by variation in sample timing during the day, particularly during warm periods when diel temperature swings may be substantial (at least 10°C).

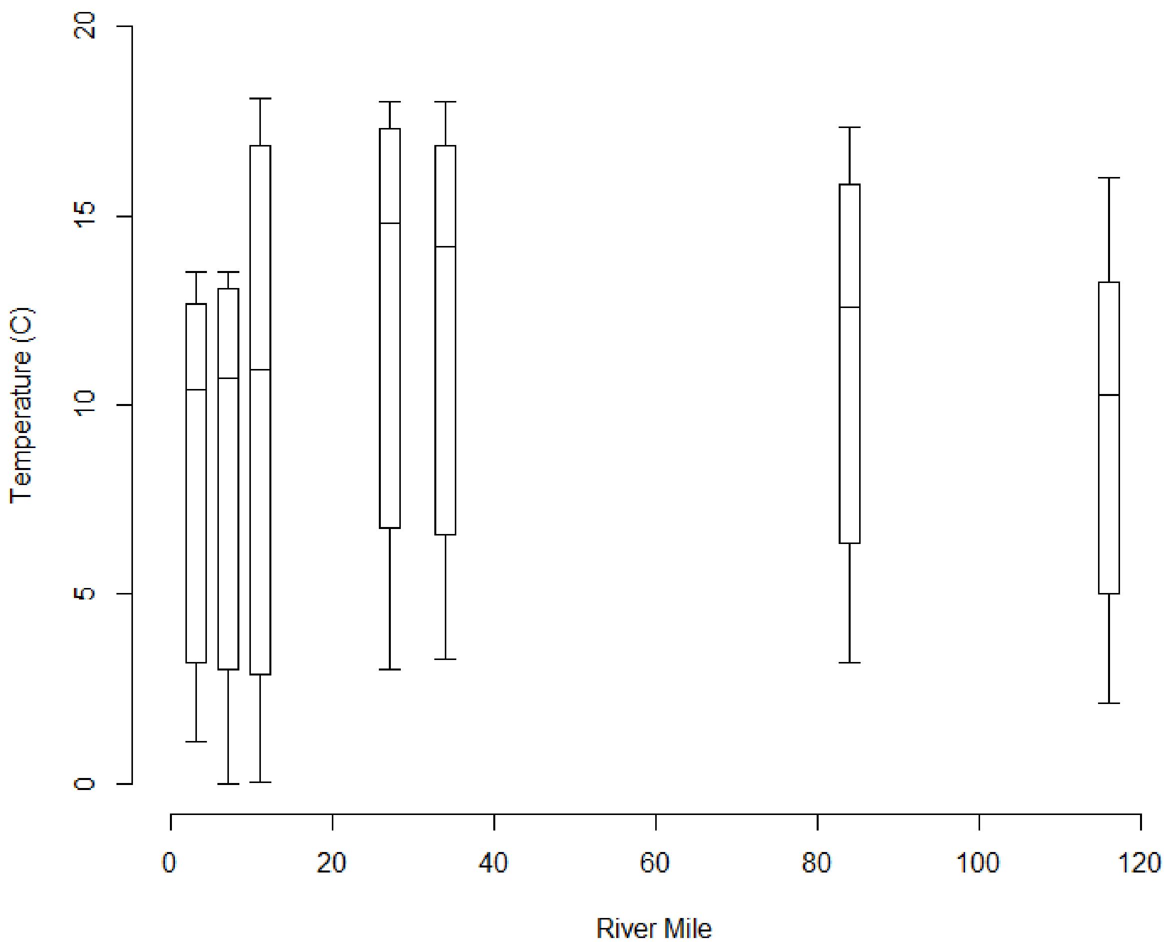

Figure 2-9. Boxplots of surface water temperatures in the Clark Fork River mainstem by river mile, 2017.

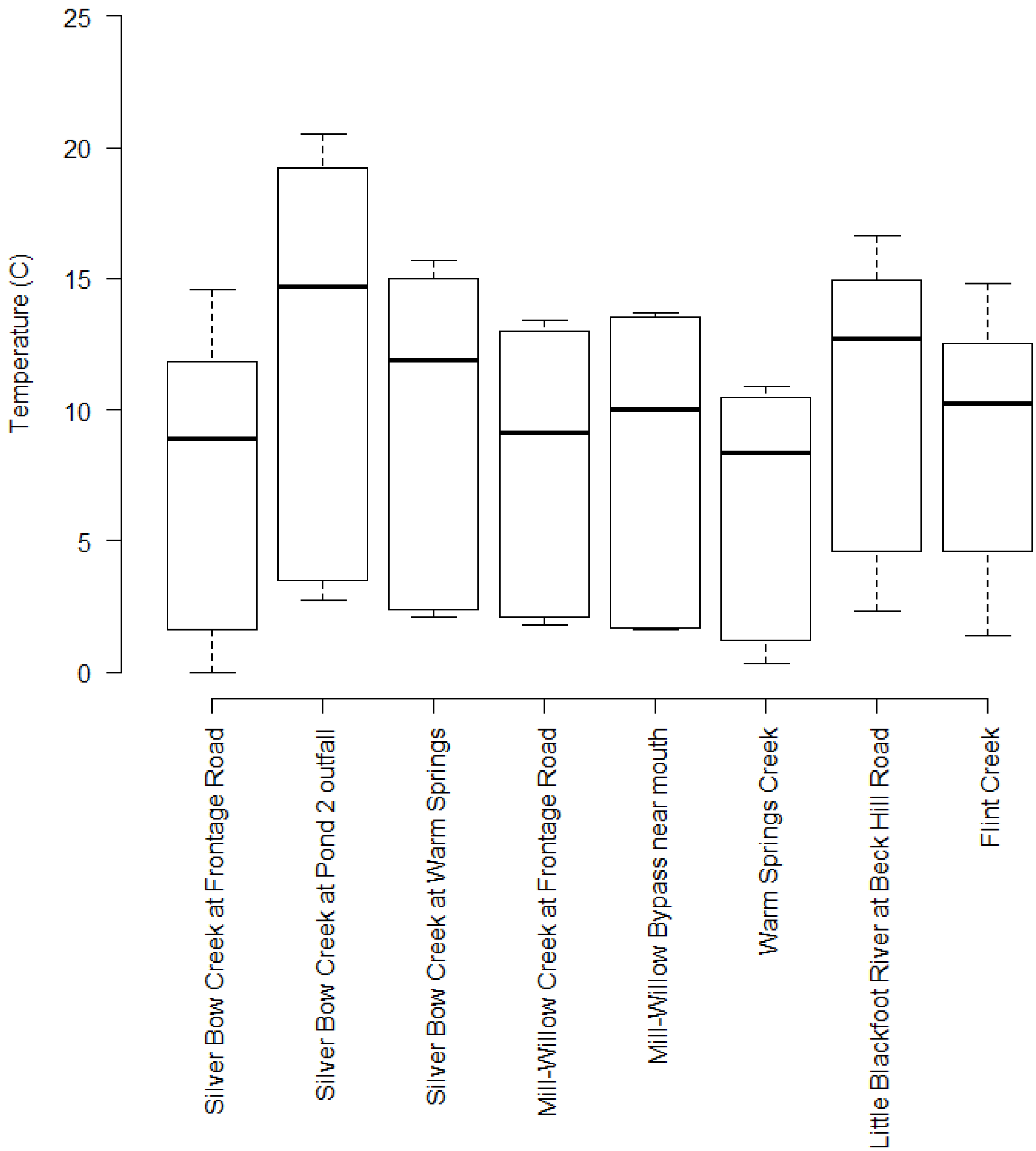

Figure 2-10. Boxplots of surface water temperatures in tributaries of the Clark Fork River, 2017.

2.3.2.2 pH

Clark Fork River mainstem pH ranged from 7.50-8.78 in 2017 (Figure 2-11). Potential water discharge restrictions could occur in the mainstem Clark Fork River between the Cottonwood Creek confluence (at Deer Lodge) and Little Blackfoot River confluence when pH exceeds 8.5 as this stream reach is designated as C-1 for water-use classification stream. One site is sampled in that reach (CFR-34; Clark Fork River at Williams-Tavenner Bridge) and pH at CFR-34 ranged from 7.67-8.36 in 2017.

In the Clark Fork River tributaries, pH ranged from 7.51-9.81 in 2017 (Figure 2-12). Potential water discharge restrictions could occur in the Mill-Willow Creek drainage (designated as a B-1 water-use classification stream; ARM 17.30.607) when pH exceeds 8.5. In the Mill-Willow Creek sites, pH was below 8.5 during all sample periods. Potential water discharge restrictions could occur in Silver Bow Creek (designated as an I water-use classification stream; ARM 17.30.607) when pH exceeds 9.5. In Silver Bow Creek at the pond 2 outfall (SBC-P2), pH exceeded 9.5 during the Q3 sample period.

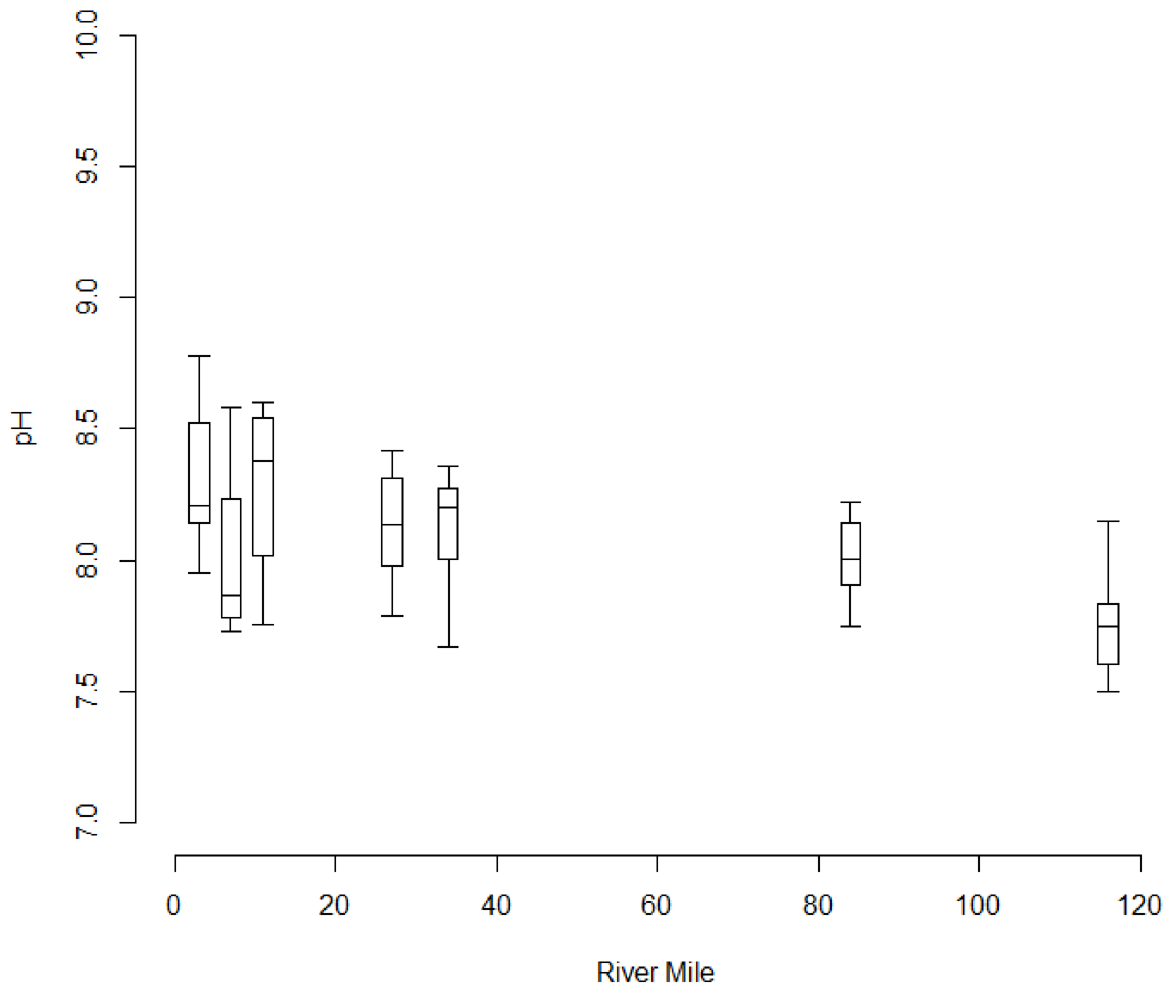

Figure 2-11. Boxplots of pH in the Clark Fork River mainstem by river mile, 2017.

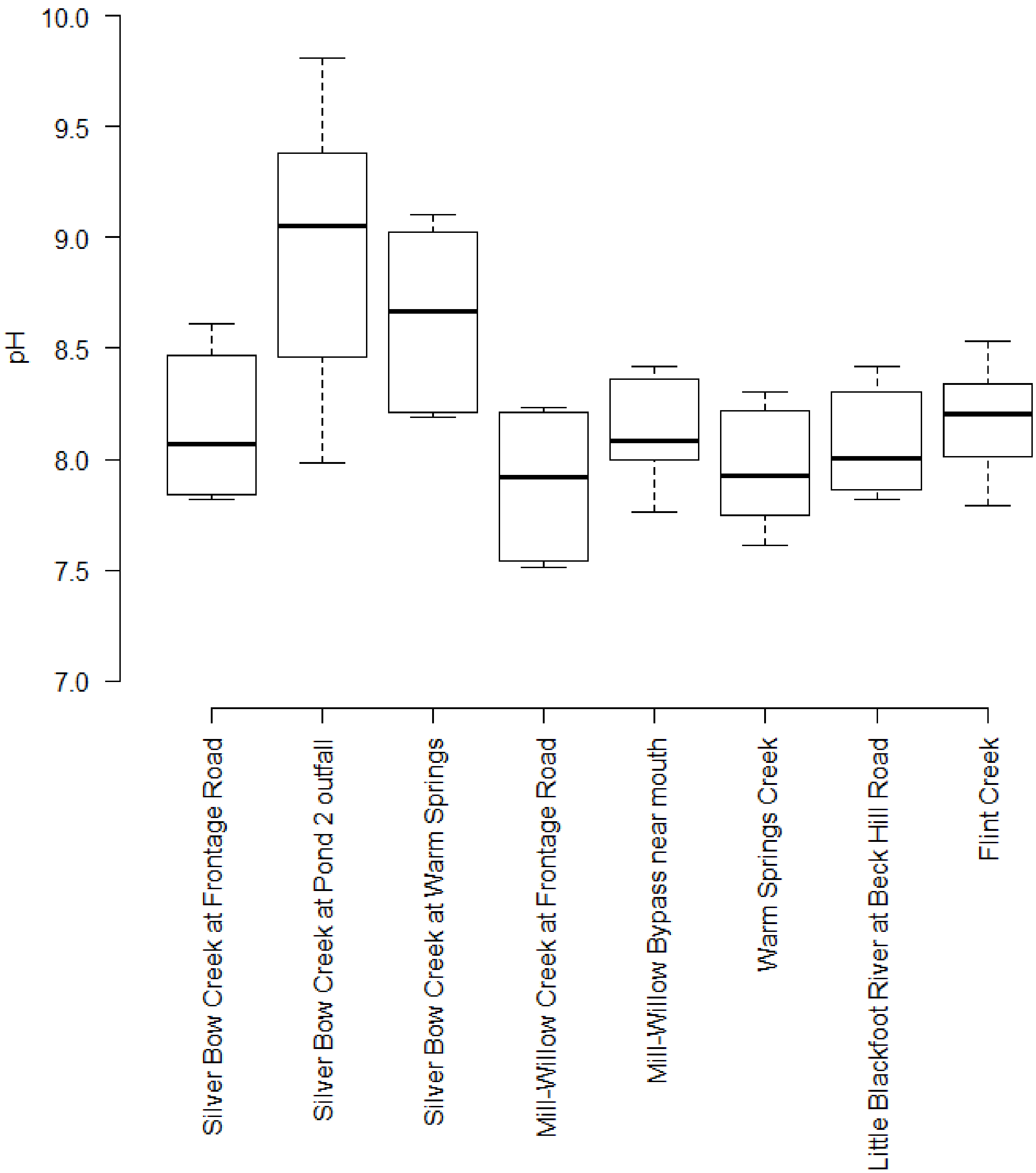

Figure 2-12. Boxplots of pH in tributaries of the Clark Fork River, 2017.

2.3.2.3 Conductivity

Conductivity in the Clark Fork River mainstem ranged from 148-573 microsiemens per centimeter (µS/cm) in 2017 (Figure 2-13). Annually, conductivity varied by 200 µS/cm or more at each site (Figure 2-13) and was generally highest during low water periods in Q1 or Q4. Longitudinally, median conductivity increased at each mainstem site from near Galen (CFR-03A) to the Williams-Tavenner Bridge (CFR-34) and then gradually decreased downstream to Turah (CFR-116A) (Figure 2-13).

In the Clark Fork River tributaries, conductivity ranged from 98-638 µS/cm in 2017 (Figure 2-14). In Silver Bow Creek, median conductivity was similar between sites above (at Frontage Road; SS-19) and below (at Pond 2 outfall; SBC-P2) the Warm Springs Ponds (Figure 2-14).

However, mean conductivity increased sharply (from 175 µS/cm to 344 µS/cm) in (Mill-Willow Creek between sites above (at Frontage Road; MCWC-MWB) and below (near mouth; MWB-SBC) the Mill-Willow Bypass.

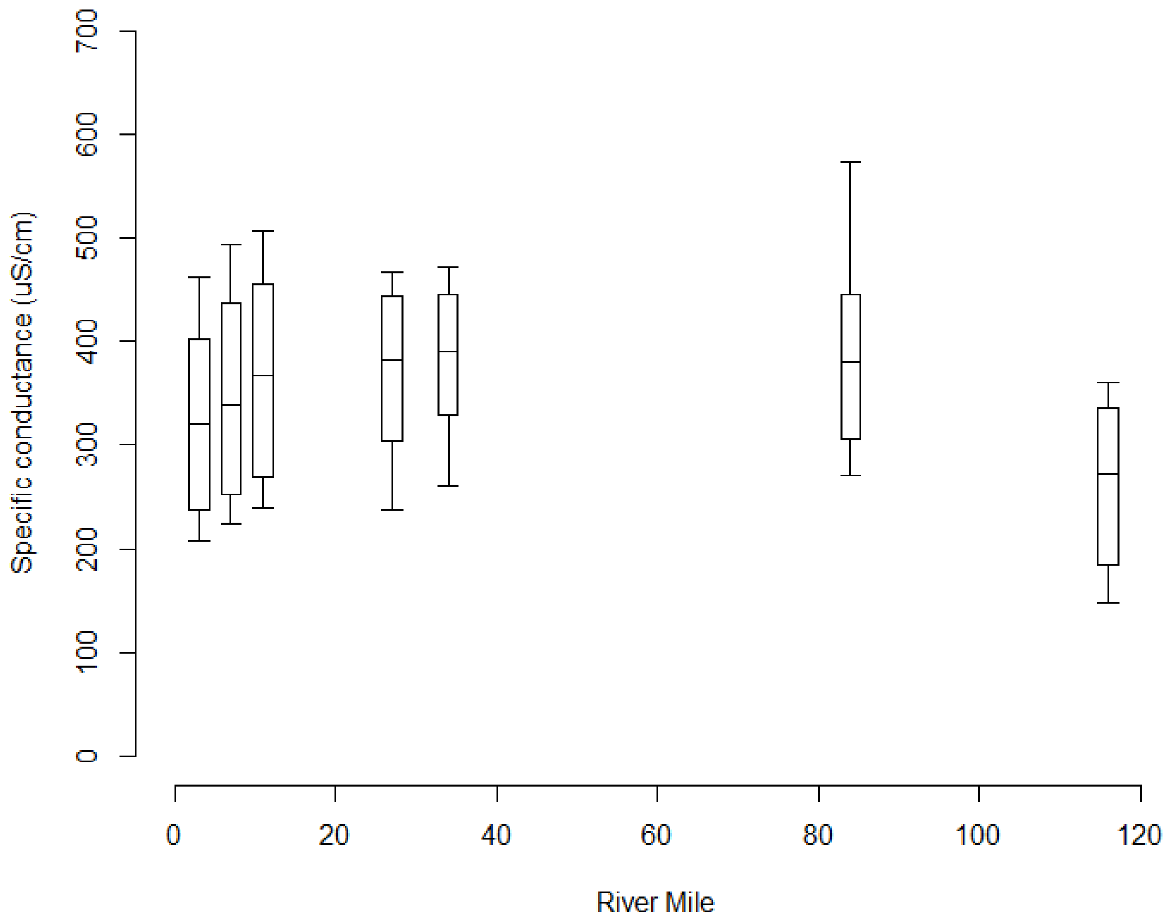

Figure 2-13. Boxplots of conductivity in the Clark Fork River mainstem by river mile, 2017.

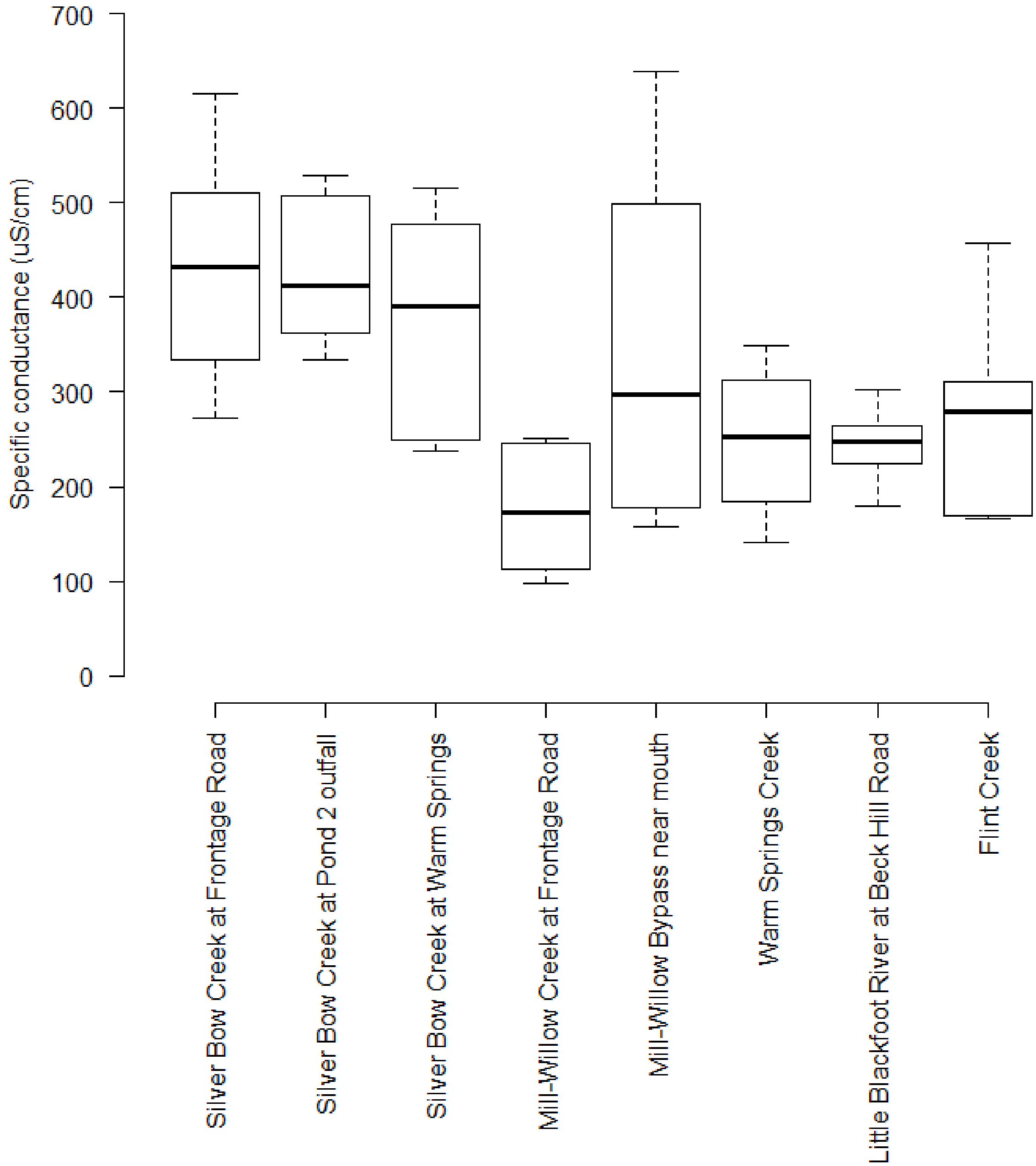

Figure 2-14. Boxplots of conductivity in tributaries of the Clark Fork River, 2017.

2.3.2.4 Dissolved Oxygen

Dissolved oxygen concentrations in the Clark Fork River mainstem ranged from 7.2-14.0 mg/L in 2017 (Figure 2-15). Most sites had variance of 5 mg/L or more annually (Figure 2-15).

In the Clark Fork River tributaries, dissolved oxygen concentrations ranged from 7.8-14.2 mg/L in 2017 (Figure 2-16). All but two dissolved oxygen concentrations measured in the CFROU in 2017 were compliant with the most restrictive freshwater aquatic life standard for dissolved oxygen DEQ [2017][11]. Sites with concentrations below that level included the Clark Fork River at Galen Road (7.2 mg/L) in Q3 and Silver Bow Creek below the Pond 2 Outfall (7.8 mg/L).

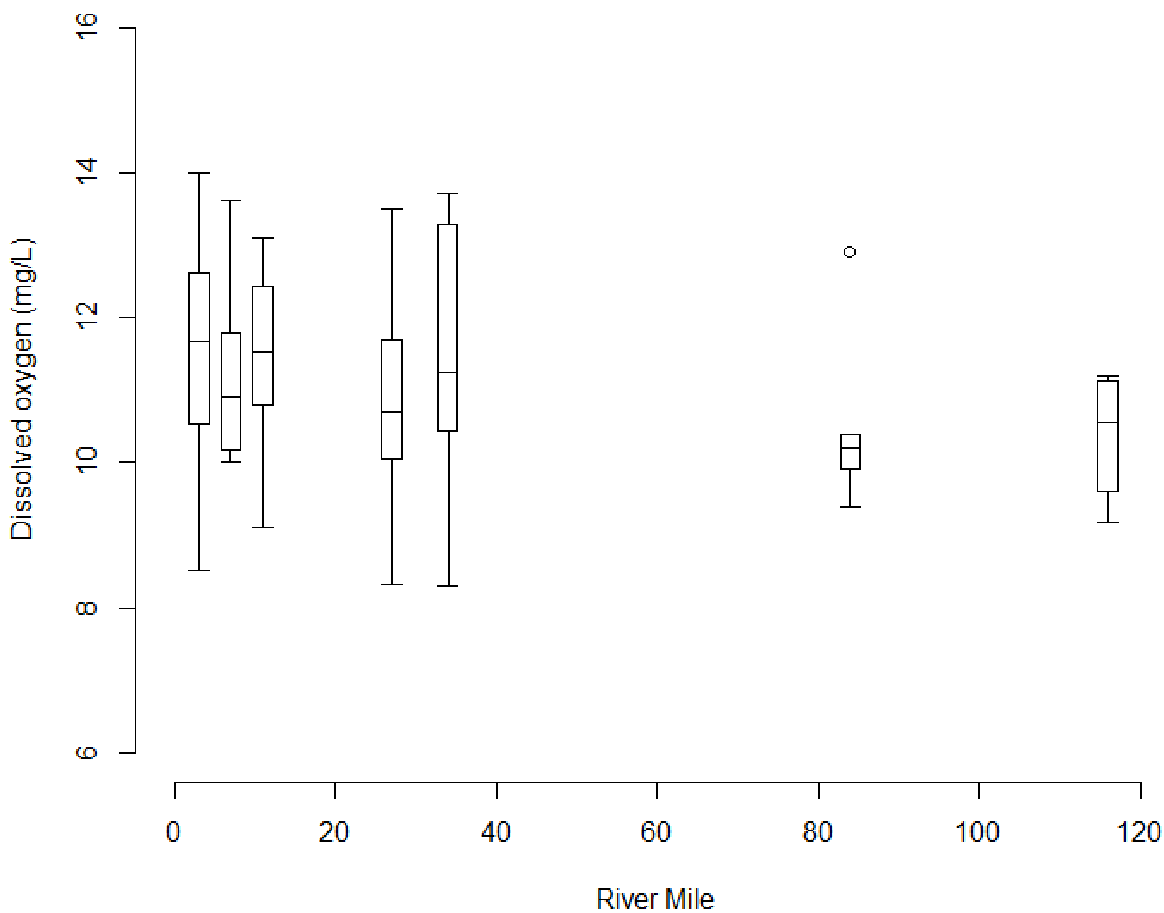

Figure 2-15. Boxplots of dissolved oxygen concentrations at mainstem sampling sites in the Clark Fork River Operable Unit, 2017.

[11] The most restrictive dissolved oxygen standard is the 1-day minimum for waters classified as A-1, B-1, B-2, C-1, or C-2 where early life stages of fish are present (8.0 mg/L).

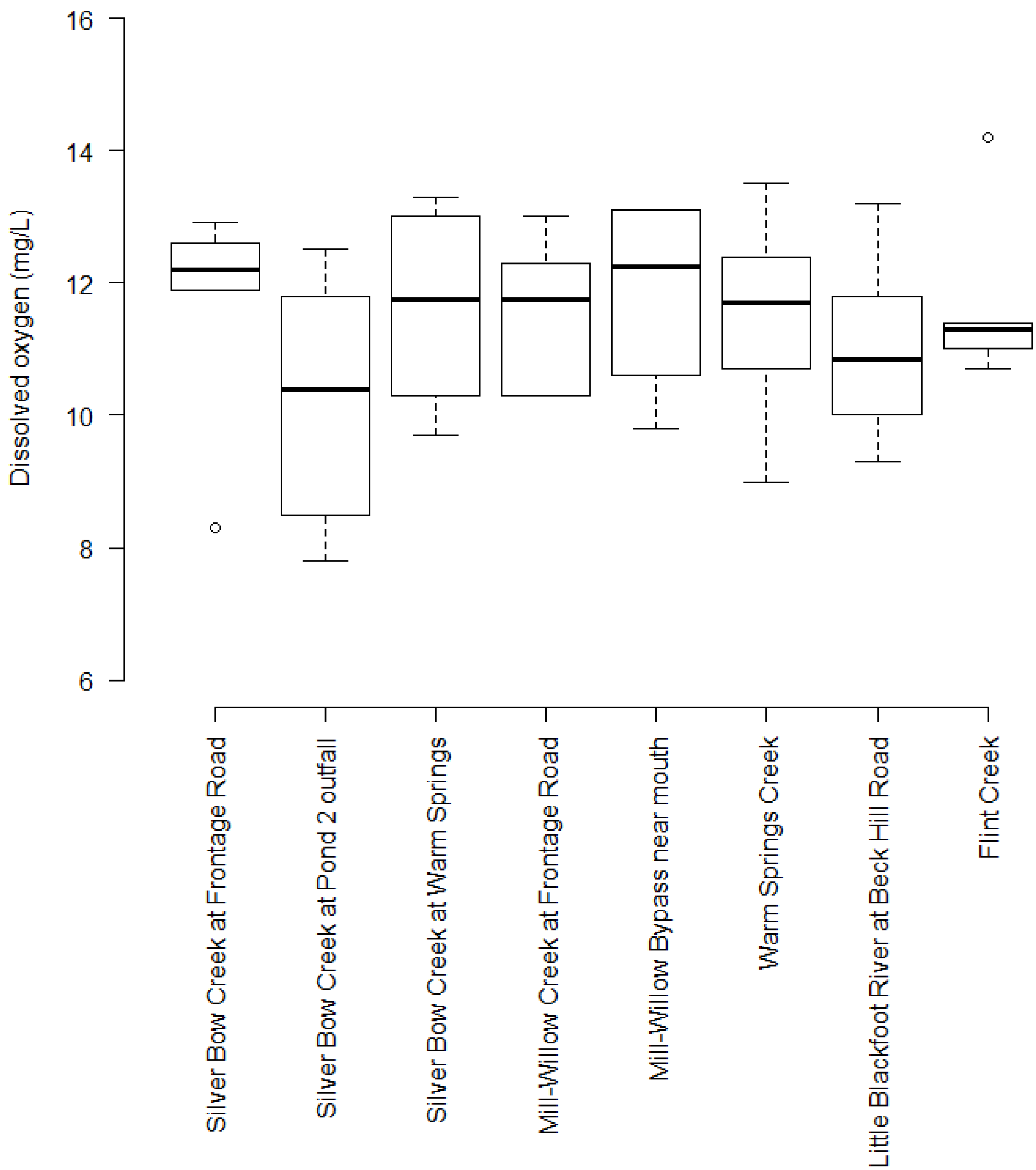

Figure 2-16. Boxplots of dissolved oxygen concentration at tributary sampling sites in the Clark Fork River Operable Unit, 2017.

2.3.2.5 Turbidity

Turbidity in the Clark Fork River mainstem ranged from 0.9-41.0 nephelometric turbidity units (NTU) in 2017 (Figure 2-17). Turbidity generally increased in the mainstem at each site downstream (Figure 2-17). Turbidity throughout the CFROU was generally high in Q2 and in Q4 at some sites.

In the Clark Fork River tributaries, turbidity ranged from 0.83-15.7 mg/L in 2017 (Figure 2-18). The highest tributary turbidity measurement occurred in Flint Creek during the Q2-Peak sample event.

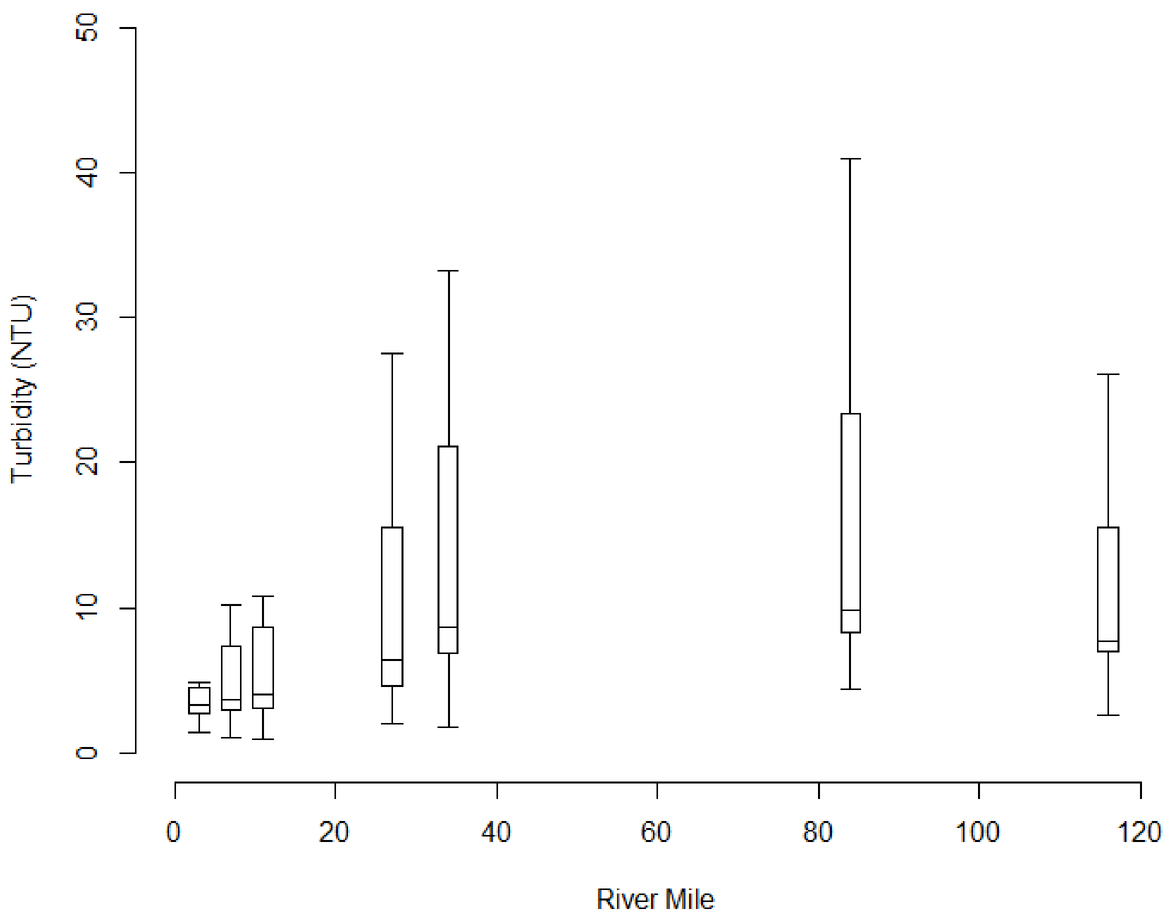

Figure 2-17. Boxplots of turbidity at mainstem sampling sites in the Clark Fork River Operable Unit, 2017.

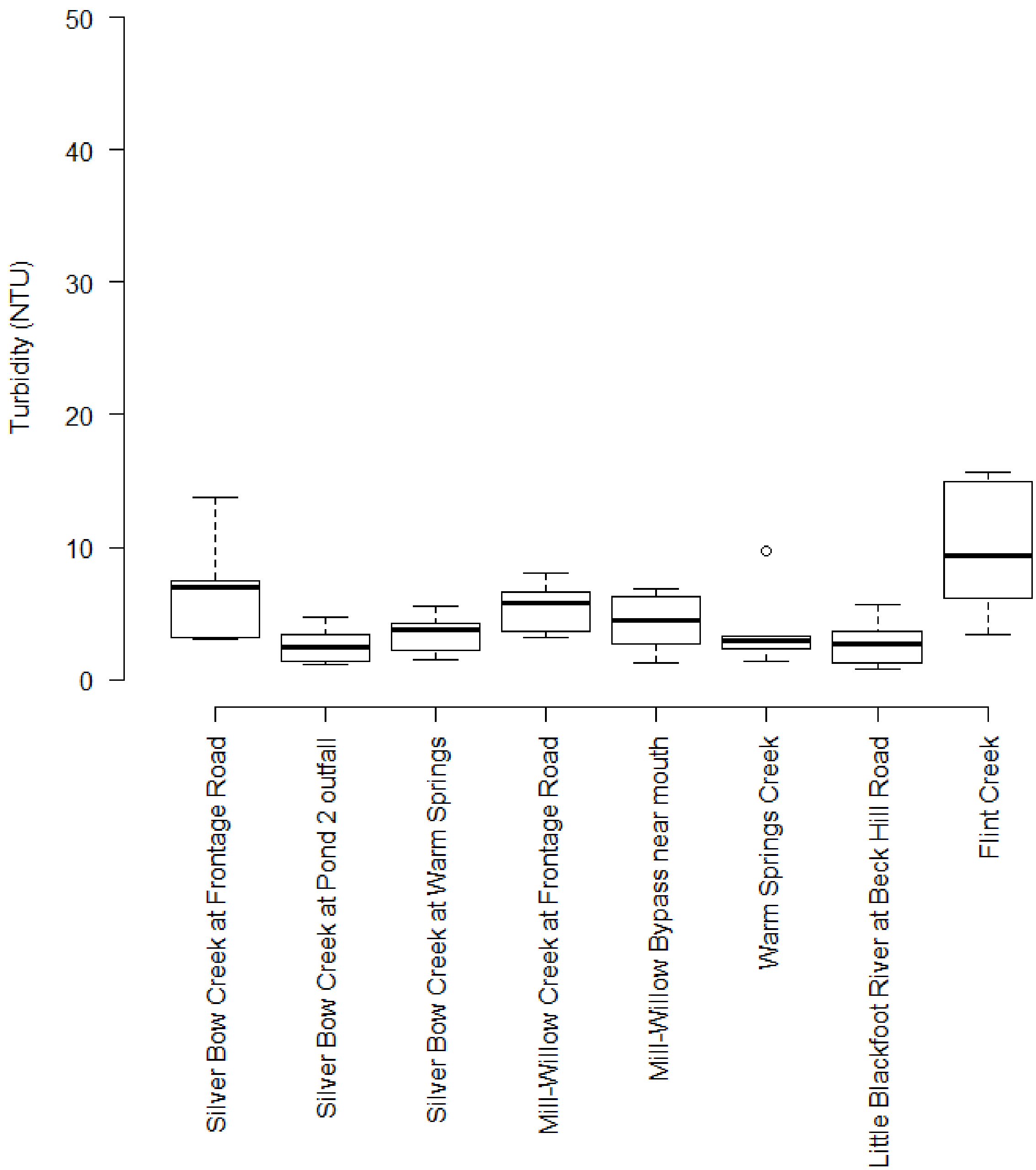

Figure 2-18. Boxplots of turbidity at tributary sampling sites in the Clark Fork River Operable Unit, 2017.

2.3.3 Total Suspended Sediment

Total suspended sediment concentrations in the Clark Fork River mainstem in 2017 ranged from 2-104 mg/L (Figure 2-19). Median concentrations increased progressively at each downstream site in the mainstem through Reach A and decreased slightly at Turah in Reach C (Figure 2-19).

Total suspended sediment concentrations in the Clark Fork River tributaries in 2017 ranged from <1-34 mg/L (Figure 2-20). The highest sample concentration was at Flint Creek during the Q2-Peak sample event.

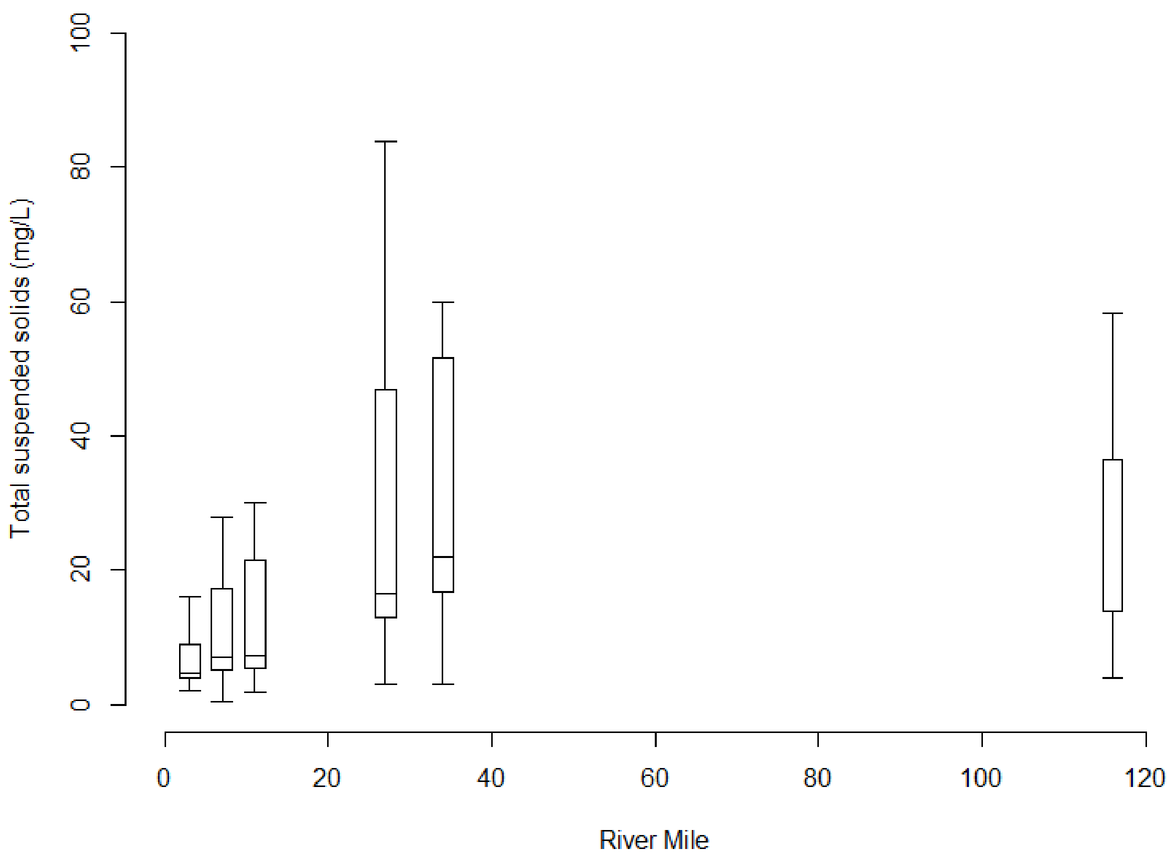

Figure 2-19. Boxplots of total suspended sediment concentrations at mainstem sampling sites in the Clark Fork River Operable Unit, 2017.

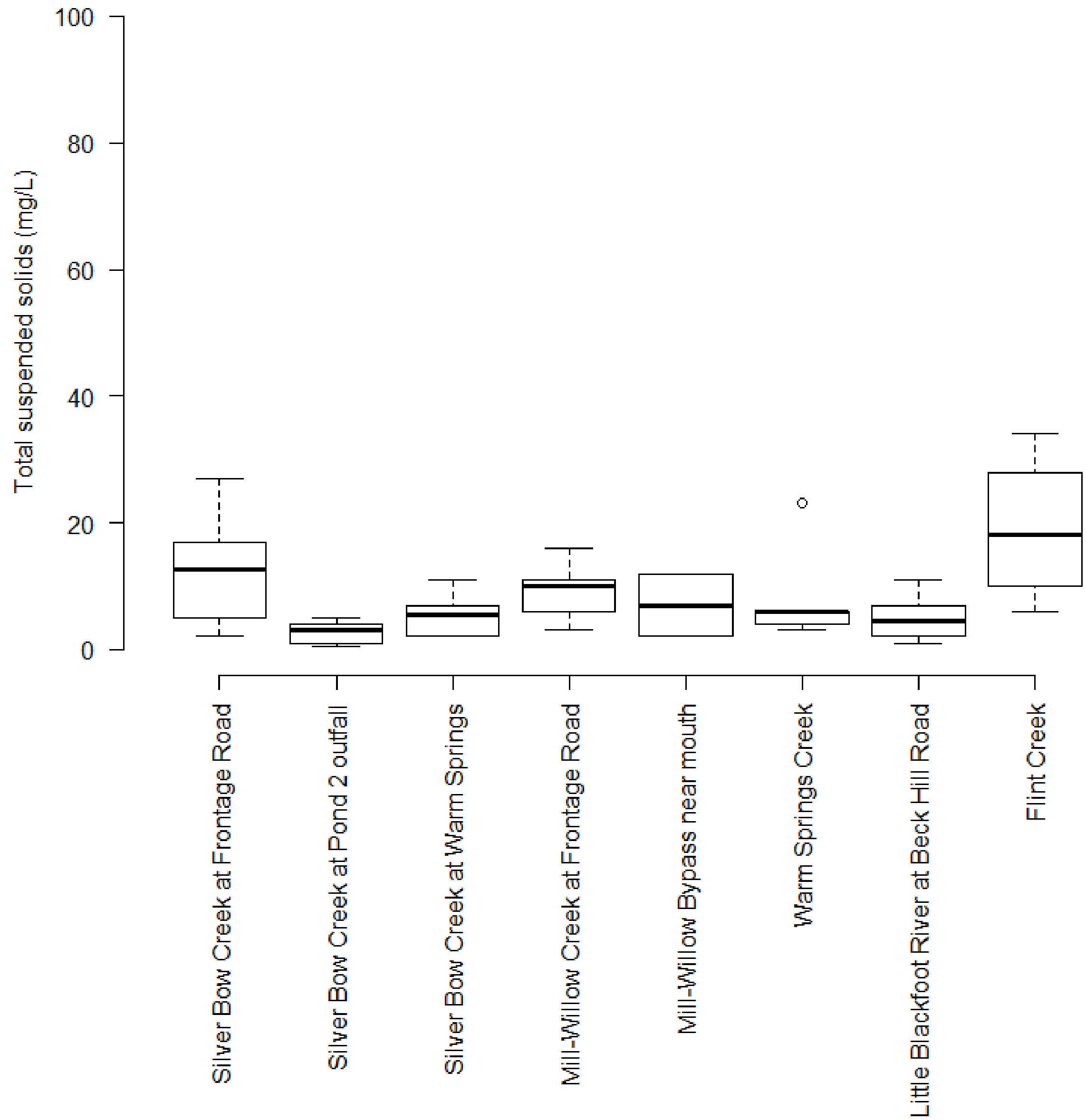

Figure 2-20. Boxplots of total suspended sediment concentrations at tributary sampling sites in the Clark Fork River Operable Unit, 2017.

2.3.4 Common Ions

2.3.4.1 Hardness

Water hardness in the Clark Fork River mainstem in 2017 ranged from 65-298 mg/L (Figure 2-21). Median water hardness in the mainstem tended to increase at each site downstream to Gemback Road (CFR-11F), was then level downstream through Reach A (to CFR-34), then decreased downstream to Turah (CFR-116A) (Figure 2-21). Hardness levels in the mainstem would be classified between “moderately hard” to “very hard”[12].

Water hardness in the Clark Fork River tributaries in 2017 ranged from 68-233 mg/L (Figure 2-22). Median hardness was lowest in Mill-Willow Creek at Frontage Road (Figure 2-22). In the other tributaries median hardness was similar except for the Silver Bow Creek sites which had slightly higher hardness (Figure 2-22). Between Mill-Willow Creek sites above (at Frontage Road; MCWC-MWB) and below (near mouth; MWB-SBC) the Mill-Willow Bypass median water hardness nearly doubled (Figure 2-22). Hardness levels in the tributaries would be classified as ranging from “moderately hard” to “very hard”.

[12] Hardness classifications: 0-60 mg/L is “soft”; 61-120 mg/L is “moderately hard”; 121-180 mg/L is “hard”; and more than 180 mg/L is “very hard” [USGS, 2015].

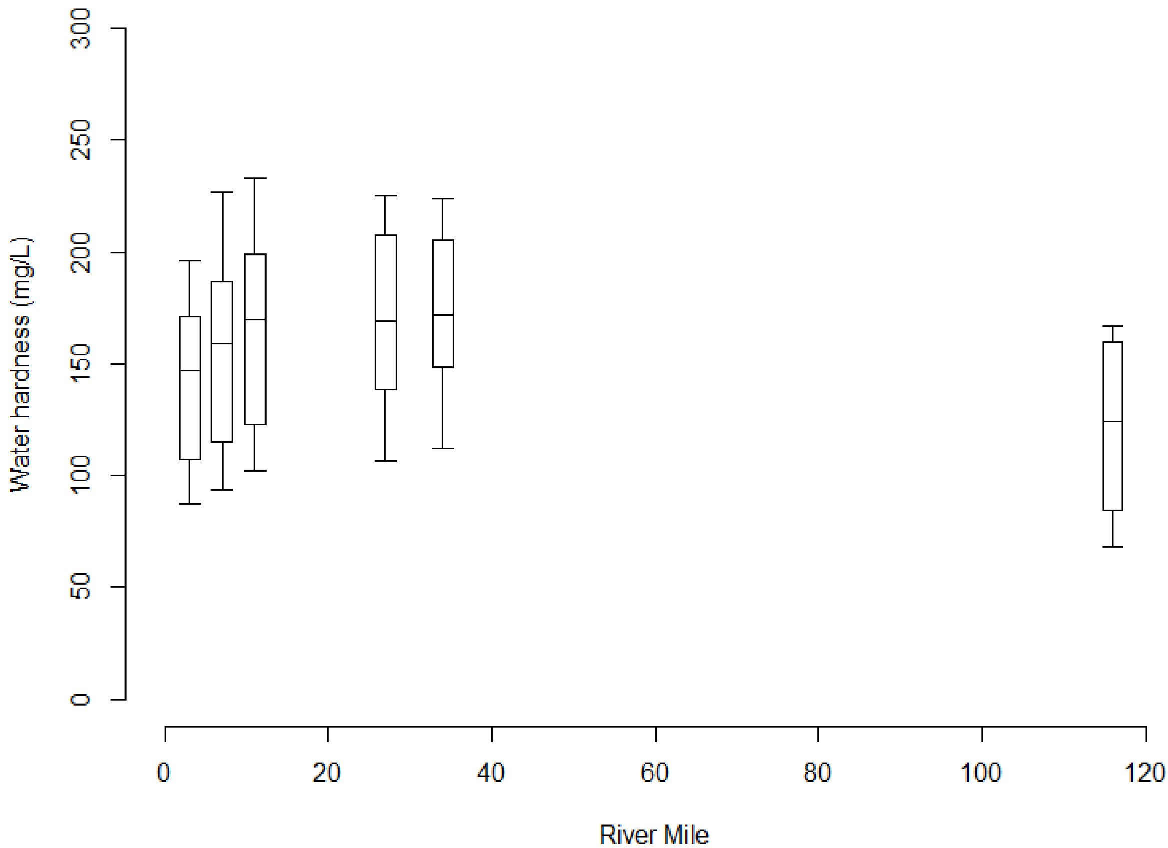

Figure 2-21. Boxplots of water hardness at mainstem sampling sites in the Clark Fork River Operable Unit, 2017.

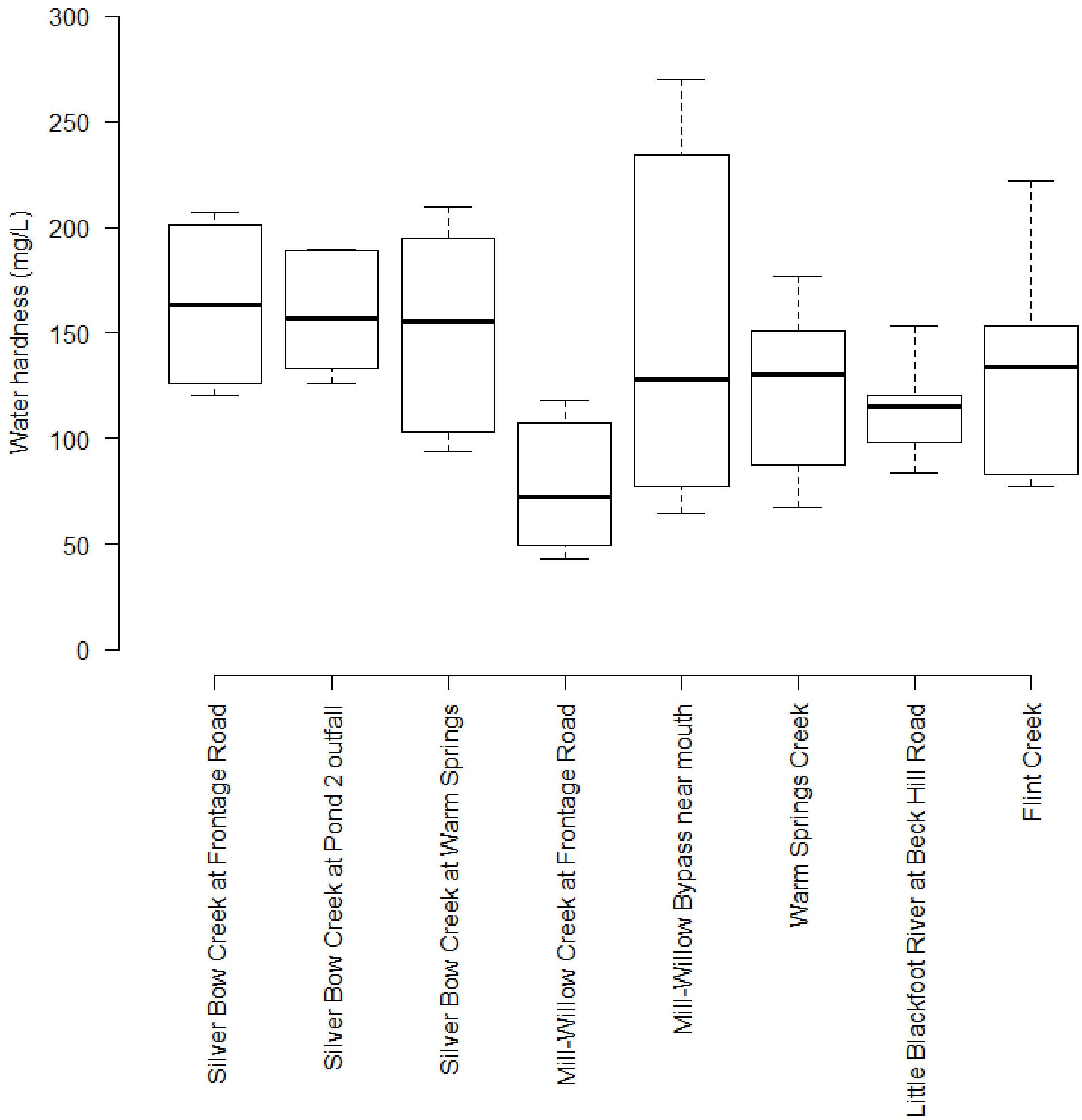

Figure 2-22. Boxplots of water hardness at tributary sampling sites in the Clark Fork River Operable Unit, 2017.

2.3.4.2 Alkalinity and Bicarbonate

In 2017, alkalinity in the Clark Fork River ranged from 58-180 mg/L (Figure 2-23) and from 43-220 mg/L in the tributaries (Figure 2-24). Bicarbonate alkalinity ranged from 70-210 mg/L in the mainstem (Figure 2-25) and from 38-260 mg/L in the tributaries (Figure 2-26). Alkalinity and bicarbonate alkalinity were generally lowest during runoff periods and highest during low water periods.

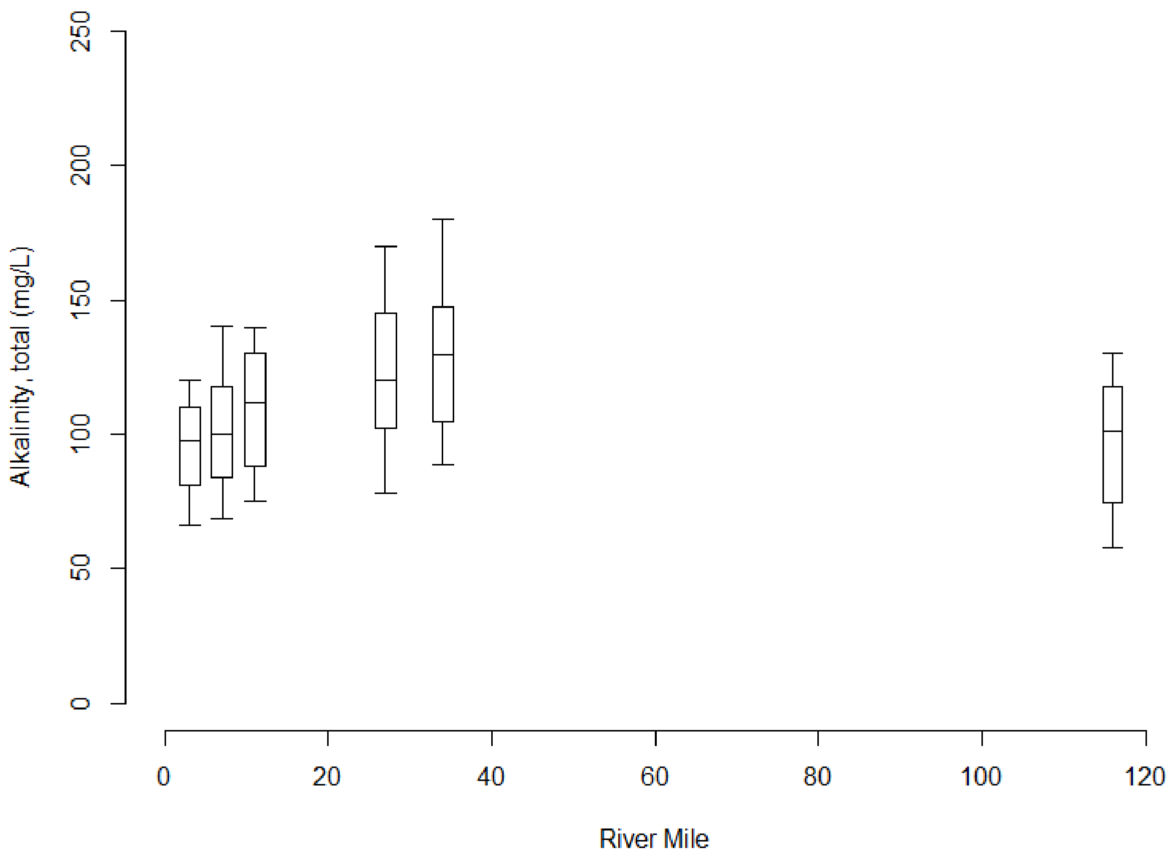

Figure 2-23. Boxplots of alkalinity at mainstem sampling sites in the Clark Fork River Operable Unit, 2017.

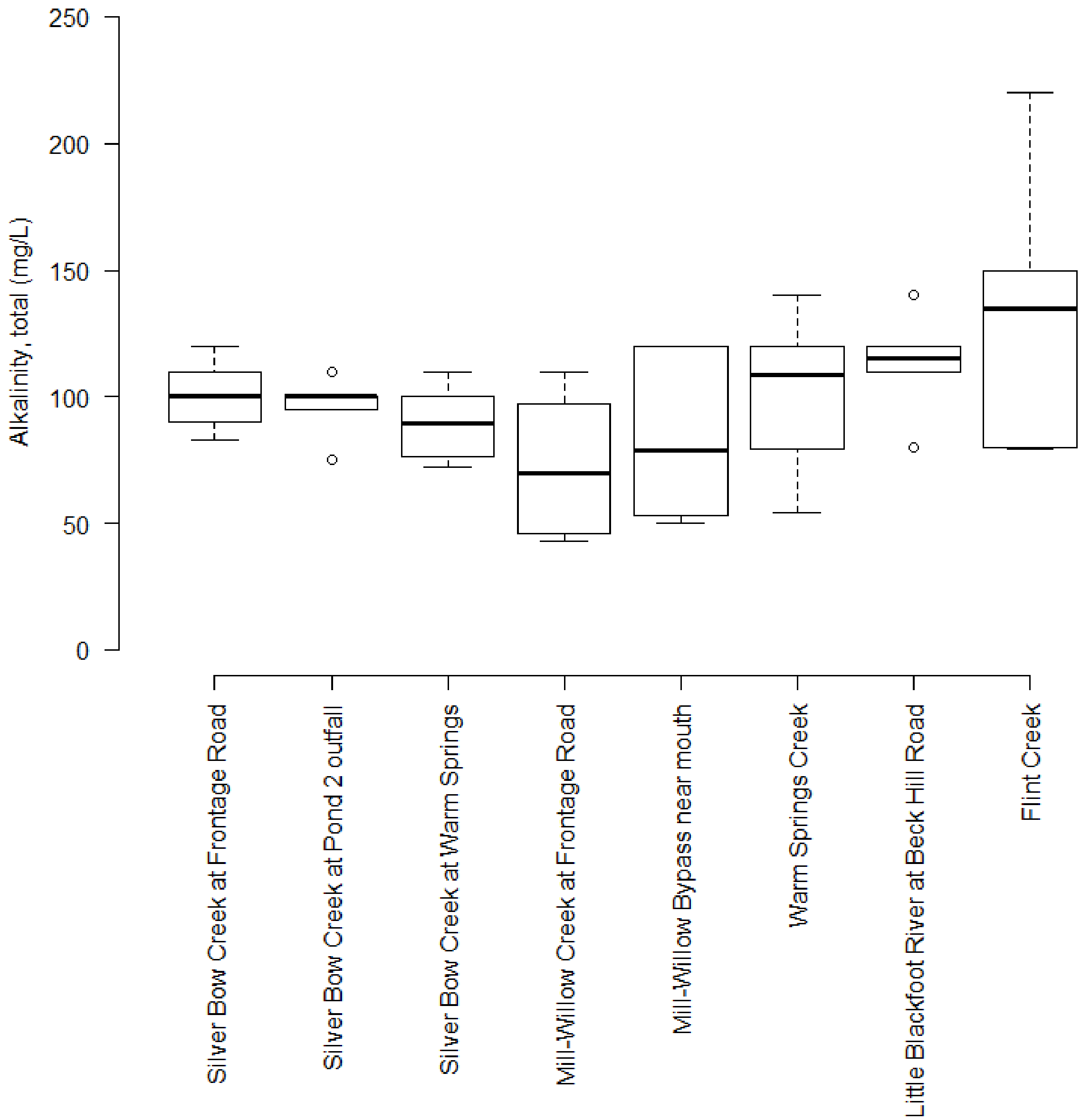

Figure 2-24. Boxplots of alkalinity at tributary sampling sites in the Clark Fork River Operable Unit, 2017.

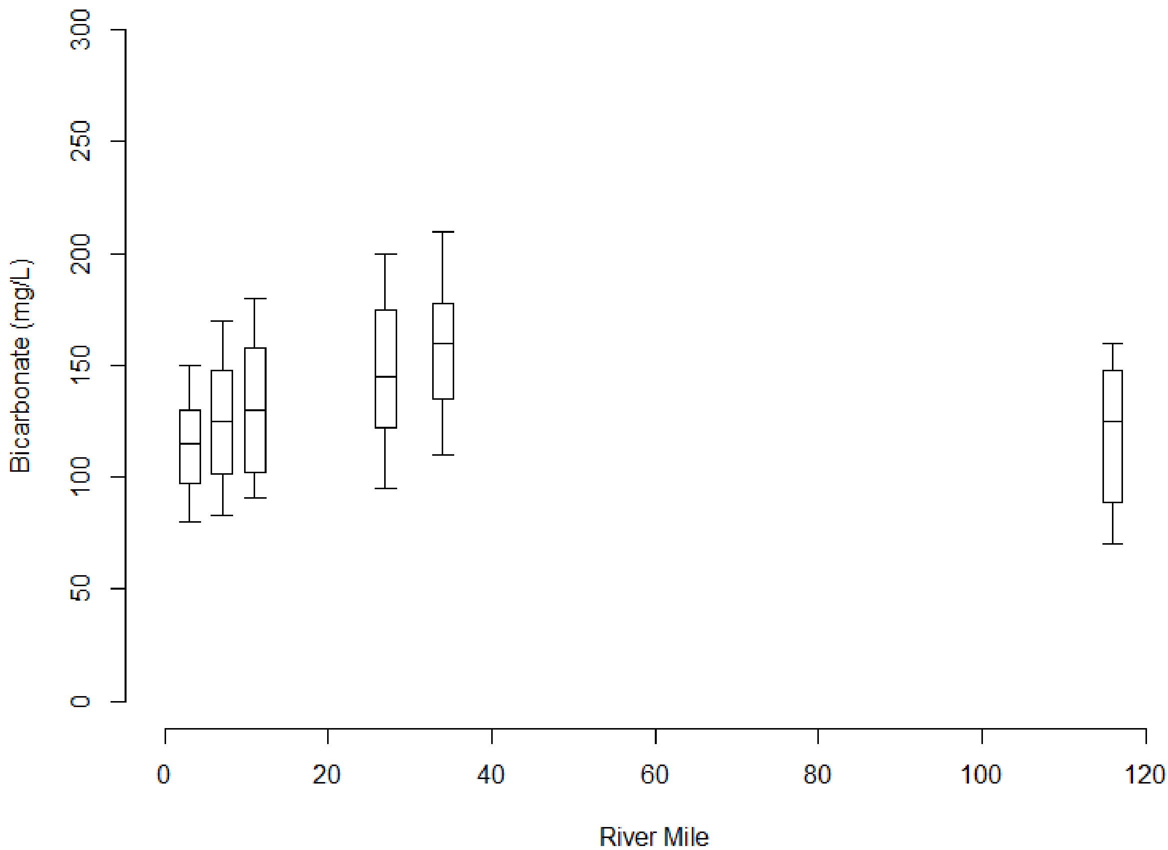

Figure 2-25. Boxplots of bicarbonate alkalinity at mainstem sampling sites in the Clark Fork River Operable Unit, 2017.

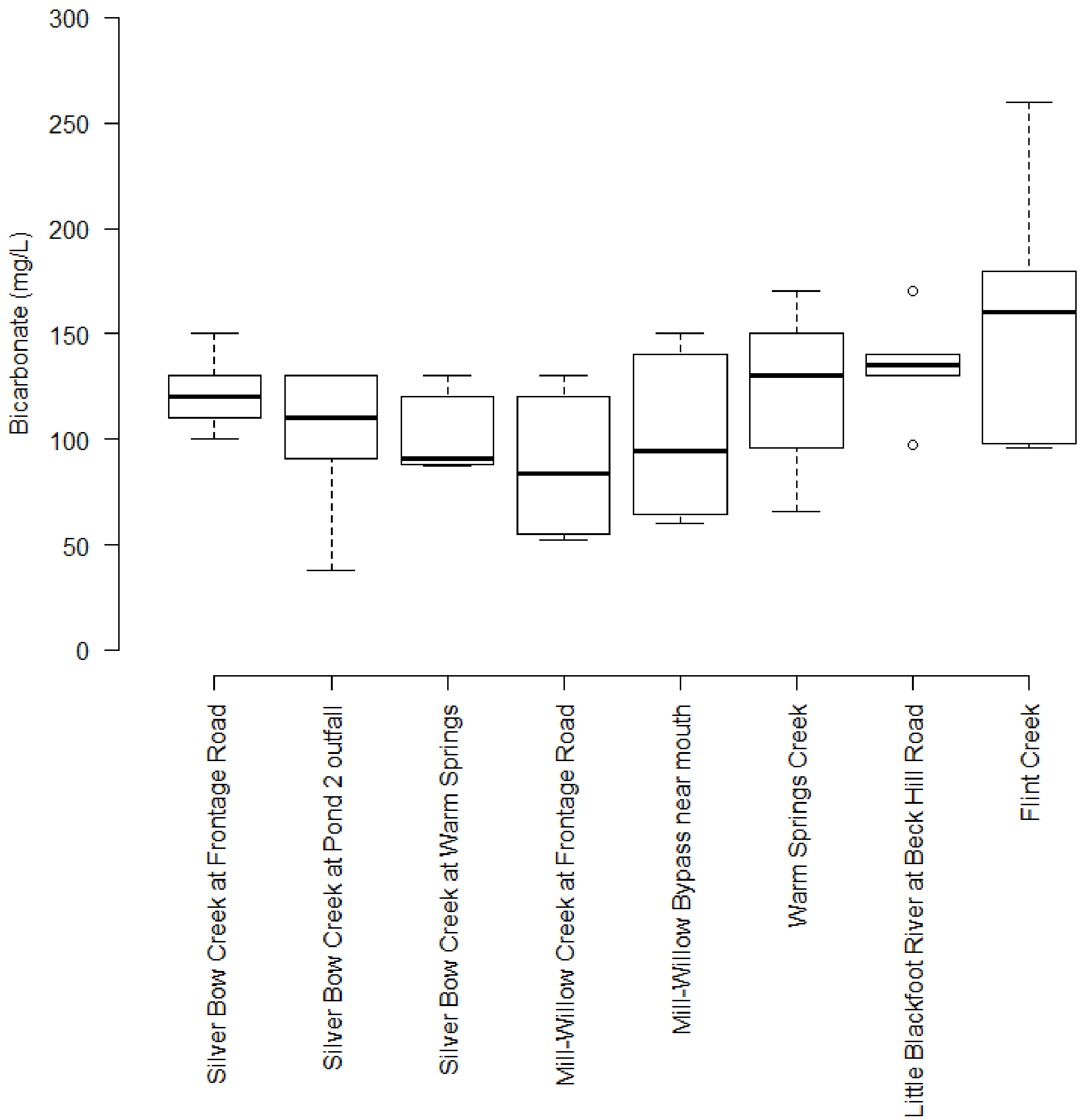

Figure 2-26. Boxplots of bicarbonate alkalinity at tributary sampling sites in the Clark Fork River Operable Unit, 2017.

2.3.4.3 Sulfate

Sulfate concentrations in the Clark Fork River mainstem in 2017 ranged from 14-89 mg/L (Figure 2-27). Median sulfate concentrations increased at each of the first three mainstem sites and then decreased at each site downstream to Turah (CFR-116A) (Figure 2-27). The lowest median sulfate concentrations were observed at Turah. Seasonally, sulfate concentrations tended to be highest during the low water sample periods and lowest during runoff periods.

Sulfate concentrations in the Clark Fork River tributaries in 2017 ranged from 5-139 mg/L (Figure 2-28). As in the mainstem, sulfate concentrations were seasonal and generally highest during low water periods and lowest during runoff periods in the tributaries. Between Silver Bow Creek sites above (at Frontage Road; SS-19) and below (at Pond 2 outfall; SBC-P2) the Warm Springs Ponds there was a modest increase in median sulfate concentrations (Figure 2-28). However, between Mill-Willow Creek sites above (at Frontage Road; MCWC-MWB) and below (near mouth; MWB-SBC) the Mill-Willow Bypass median sulfate concentrations increased by approximately five times (Figure 2-28). Sulfate concentrations were relatively low (i.e., less than 50 mg/L) in other tributary sites (Figure 2-28).

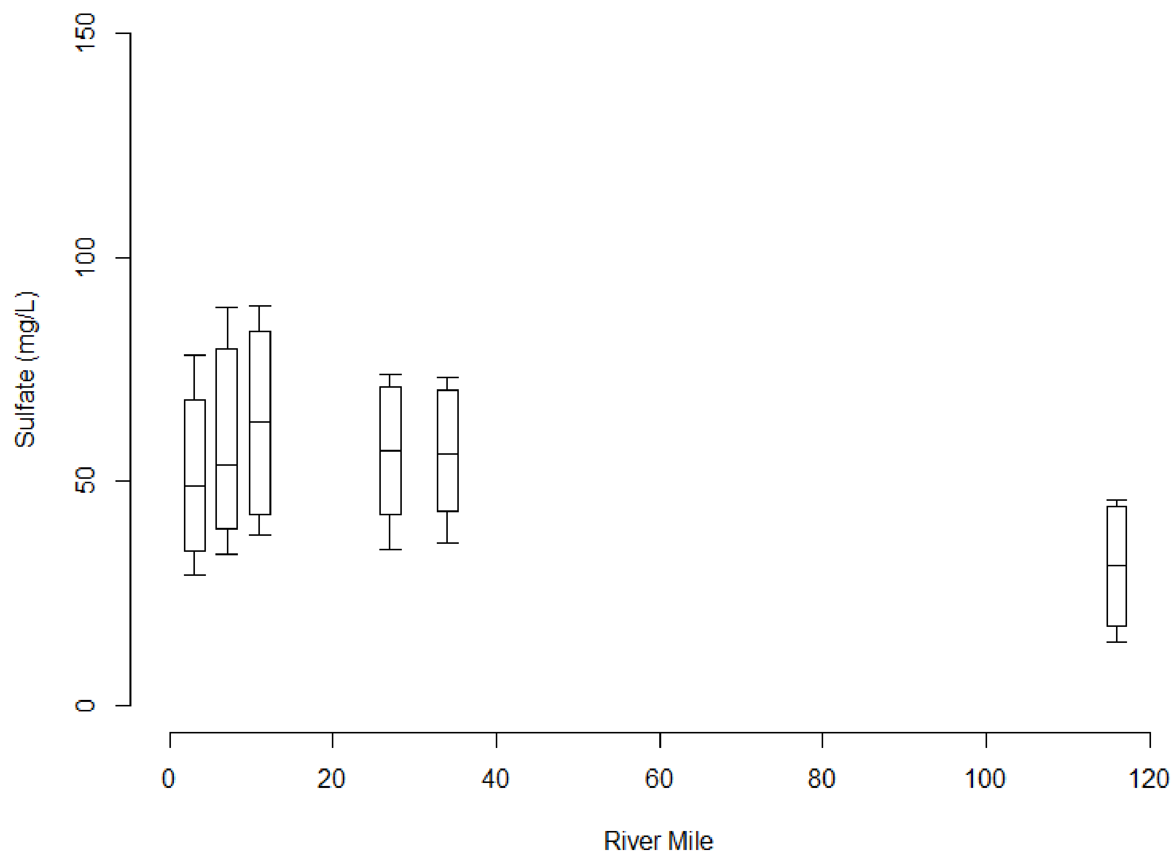

Figure 2-27. Boxplots of sulfate concentrations at mainstem sampling sites in the Clark Fork River Operable Unit, 2017.

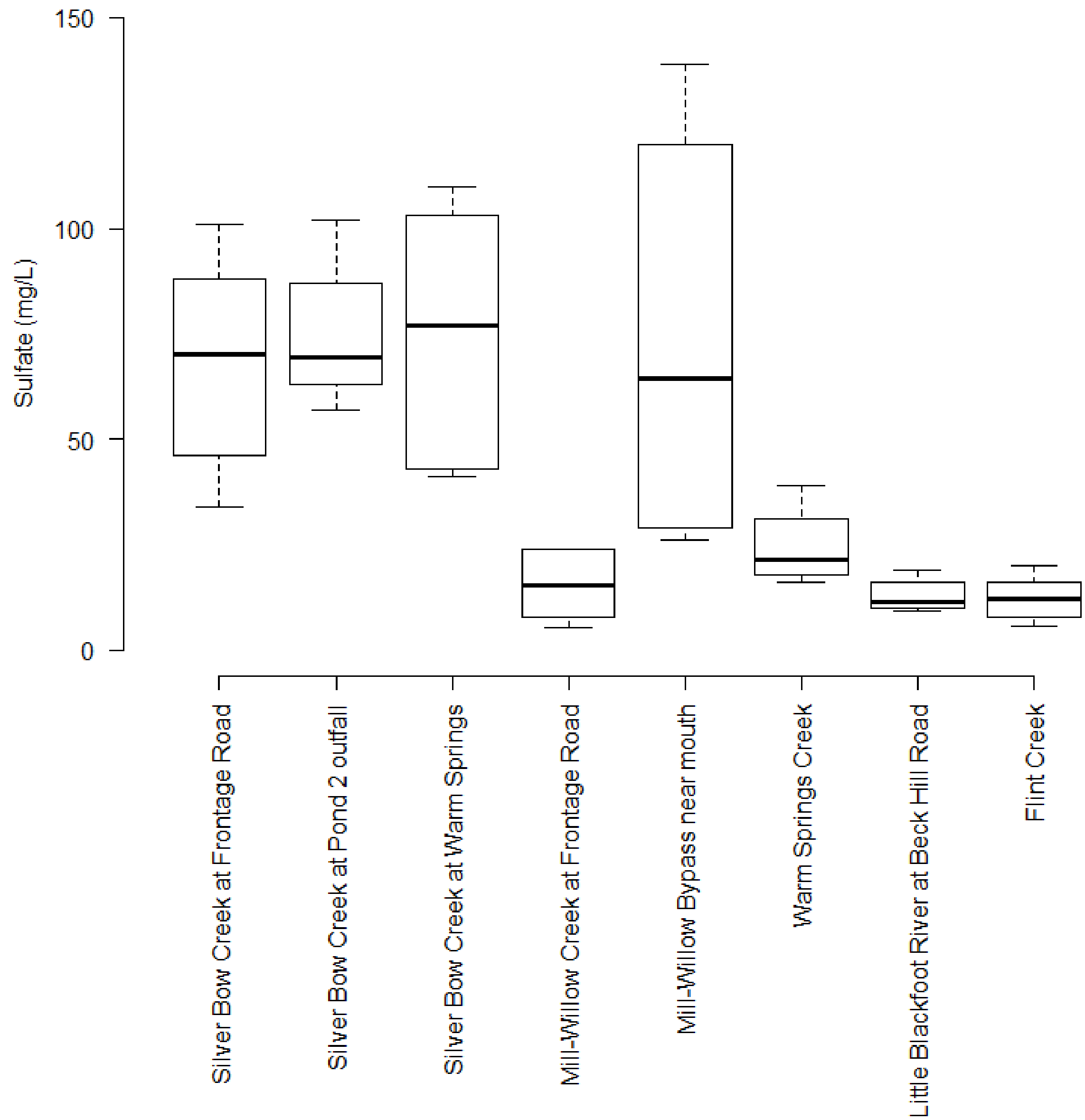

Figure 2-28. Boxplots of sulfate concentrations at tributary sampling sites in the Clark Fork River Operable Unit, 2017.

2.3.5 Nutrients

2.3.5.1 Total Nitrogen

Total nitrogen concentrations in the Clark Fork River mainstem in 2017 ranged from 0.11-0.45 mg/L (Table 2-5). Median total nitrogen concentrations increased at each Reach A site downstream to Williams-Tavenner Bridge at river mile 34 (CFR-34) and then decreased downstream at Turah (Figure 2-29). Sites in the lower portion of Reach A (CFR-27H and CFR-34) had median total nitrogen concentrations above the total nitrogen standard (Figure 2-29) although that standard only technically applied to the Q3 samples. In Q3, the mainstem samples from CFR-27H and CFR-34 exceeded the standard (Table 2-5).

Total nitrogen concentrations in the Clark Fork River tributaries in 2017 ranged from 0.05-1.72mg/L (Table 2-5). All Silver Bow Creek samples in 2017 exceeded the total nitrogen standard during Q3 and the sites at Frontage Road (SS-19) and at the Pond 2 Outfall (SBC-P2) also exceeded the applicable standard during the Q2-Falling sample period (Figure 2-30). In addition, the total nitrogen sample from Flint Creek in Q3 also exceeded the total nitrogen (Table 2-5). Total nitrogen concentrations in Silver Bow Creek above the Warm Springs Ponds (at Frontage Road; SS-19) were substantially higher than either site downstream from the ponds (Figure 2-30). Total nitrogen concentrations in the two Mill-Willow Creek sites were similar (Figure 2-30).

Table 2-5. Total nitrogen concentrations (mg/L) at Clark Fork River Operable Unit monitoring stations, 2017.

Site ID	Site Location	Sample Period					
		Q1	Q2			Q3	Q4
			Rising	Peak	Falling		
Mainstem Sites							
CFR-03A	Clark Fork River near Galen	0.26	0.22	0.22	0.15	0.14	0.19
CFR-07D	Clark Fork River at Galen Road	0.34	0.25	0.20	0.12	0.14	0.28
CFR-11F	Clark Fork River at Gemback Road	0.37	0.30	0.26	0.14	0.18	0.28
CFR-27H	Clark Fork River at Deer Lodge	0.45	0.32	0.27	0.22	0.40	0.35
CFR-34	Clark Fork River at Williams-Tavenner Bridge	0.42	0.44	0.32	0.27	0.32	0.35
CFR-116A	Clark Fork River at Turah	0.28	0.28	0.31	0.14	0.11	0.18
Tributary Sites							
SS-19	Silver Bow Creek at Frontage Road	1.72	0.59	0.40	0.38	0.85	0.89
SBC-P2	Silver Bow Creek at Pond 2 outfall	0.53	0.29	0.50	0.47	0.61	0.38
SS-25	Silver Bow Creek at Warm Springs	0.49	0.23	0.27	0.23	0.37	0.28
MCWC-MWB	Mill-Willow Creek at Frontage Road	0.16	0.11	0.15	0.13	0.10	0.16
MWB-SBC	Mill-Willow Bypass near mouth	0.20	0.09	0.22	0.14	0.15	0.12
WSC-SBC	Warm Springs Creek near mouth	0.09	0.05	0.17	0.08	0.06	0.09
LBR-CFR-02	Little Blackfoot River at Beck Hill Road	0.16	0.17	0.26	0.15	0.06	0.13
FC-CFR	Flint Creek near mouth	0.40	0.31	0.28	0.22	0.36	0.26

--- Not sampled.

ND Not detected at analytical reporting limit.

(shaded) Exceeds Clark Fork River total nitrogen standard (0.30 mg/L; applies June 21 to September 21; ARM 17.30.631) and Middle Rockies Ecoregion total nitrogen standard (also 0.30 mg/L; applies July 1 to September 30; DEQ [2014]).

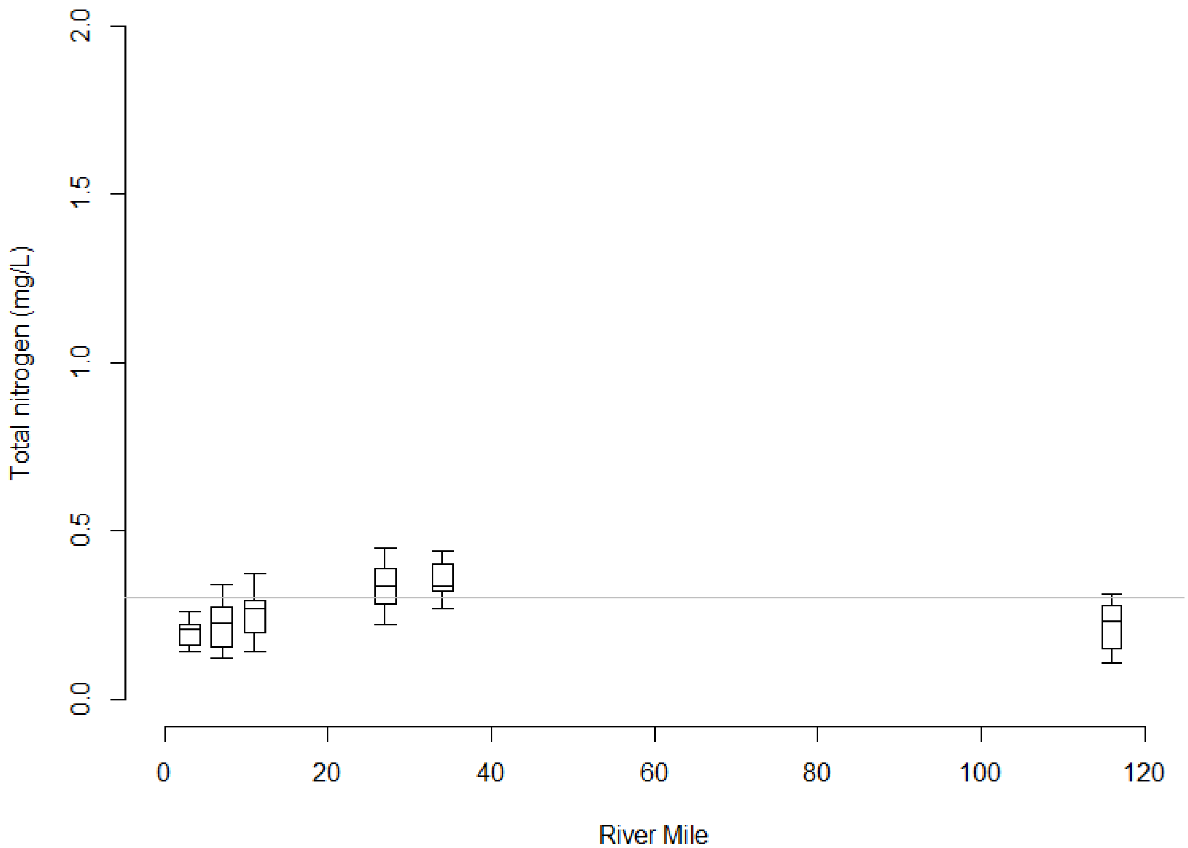

Figure 2-29. Boxplots of total nitrogen concentrations (mg/L) at Clark Fork River mainstem monitoring stations, 2017. Horizontal line represents total nitrogen standard [DEQ, 2014].

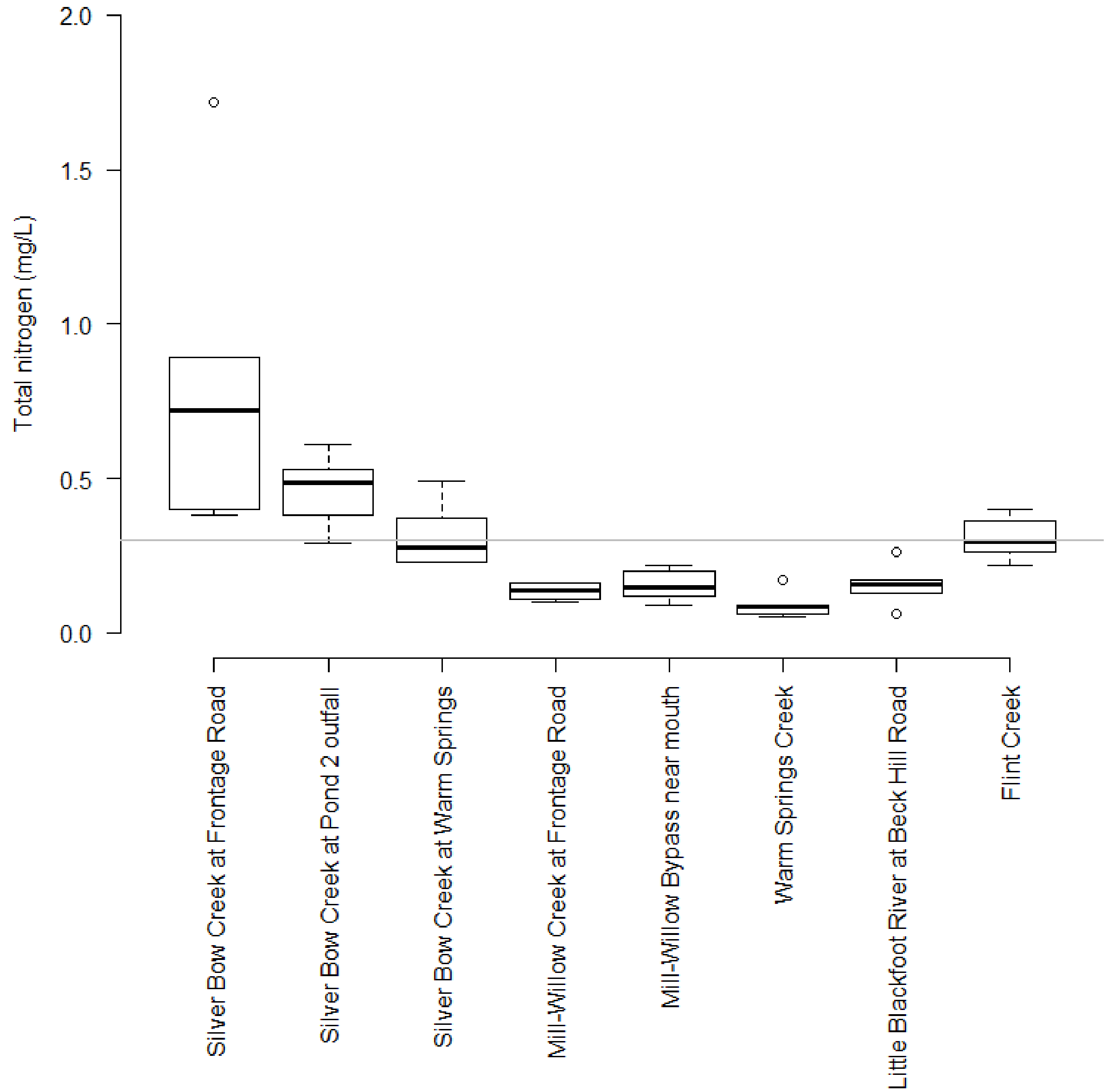

Figure 2-30. Boxplots of total nitrogen concentrations (mg/L) at Clark Fork River tributary monitoring stations, 2017. Horizontal line represents total nitrogen standard [DEQ, 2014].

2.3.5.2 Nitrate Plus Nitrite Nitrogen

Nitrate plus nitrite nitrogen concentrations in the Clark Fork River mainstem in 2017 ranged from <0.02-0.24 mg/L (Table 2-6). In the mainstem, median concentrations were highest at Williams-Tavenner Bridge (CFR-34) and lowest near Galen (CFR-03A) (Figure 2-31).

Nitrate plus nitrite nitrogen concentrations in the Clark Fork River tributaries in 2017 ranged from <0.02-1.52 mg/L (Table 2-6). In the tributaries, all sites except Silver Bow Creek at Frontage Road (SS-19) had concentrations below 0.16 mg/L (Table 2-6). In Silver Bow Creek at Frontage Road, concentrations were at times (e.g., Q1, Q3, Q4) substantially higher than any other sites in the CFROU. However, during high water periods (Q2), concentrations at SS-19 were similar to other sites (Figure 2-31; Figure 2-32).

Table 2-6. Nitrate plus nitrite nitrogen concentrations (mg/L) at Clark Fork River Operable Unit monitoring stations, 2017.

Site ID	Site Location	Sample Period					
		Q1	Q2			Q3	Q4
			Rising	Peak	Falling		
Mainstem Sites							
CFR-03A	Clark Fork River near Galen	0.05	ND	ND	ND	ND	ND
CFR-07D	Clark Fork River at Galen Road	ND	0.02	ND	ND	ND	0.10
CFR-11F	Clark Fork River at Gemback Road	0.16	0.03	ND	ND	ND	0.09
CFR-27H	Clark Fork River at Deer Lodge	0.21	0.08	0.05	0.06	0.24	0.13
CFR-34	Clark Fork River at Williams-Tavenner Bridge	0.22	0.09	0.06	0.06	0.16	0.16
CFR-116A	Clark Fork River at Turah	0.08	0.03	0.03	ND	ND	0.04
Tributary Sites							
SS-19	Silver Bow Creek at Frontage Road	1.52	0.32	0.07	0.03	0.59	0.6
SBC-P2	Silver Bow Creek at Pond 2 outfall	0.15	ND	0.04	ND	ND	ND
SS-25	Silver Bow Creek at Warm Springs	0.10	ND	ND	ND	ND	ND
MCWC-MWB	Mill-Willow Creek at Frontage Road	0.02	ND	ND	ND	ND	0.04
MWB-SBC	Mill-Willow Bypass near mouth	ND	ND	ND	ND	ND	ND
WSC-SBC	Warm Springs Creek near mouth	0.02	0.02	0.02	0.03	ND	0.06
LBR-CFR-02	Little Blackfoot River at Beck Hill Road	ND	ND	ND	ND	ND	ND
FC-CFR	Flint Creek near mouth	0.12	0.02	0.03	0.02	0.59	0.08

--- Not sampled.

ND Not detected at analytical reporting limit.

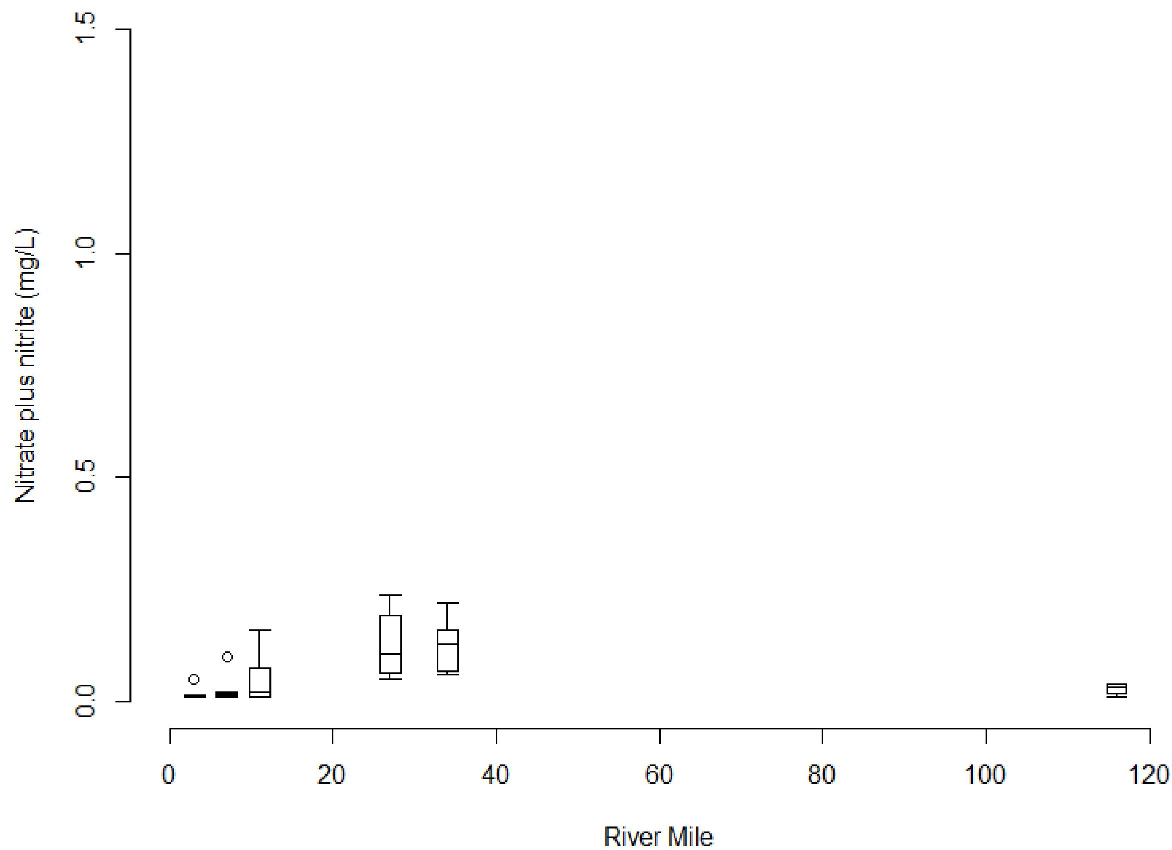

Figure 2-31. Boxplots of nitrate plus nitrite nitrogen concentrations (mg/L) at Clark Fork River mainstem monitoring stations, 2017.

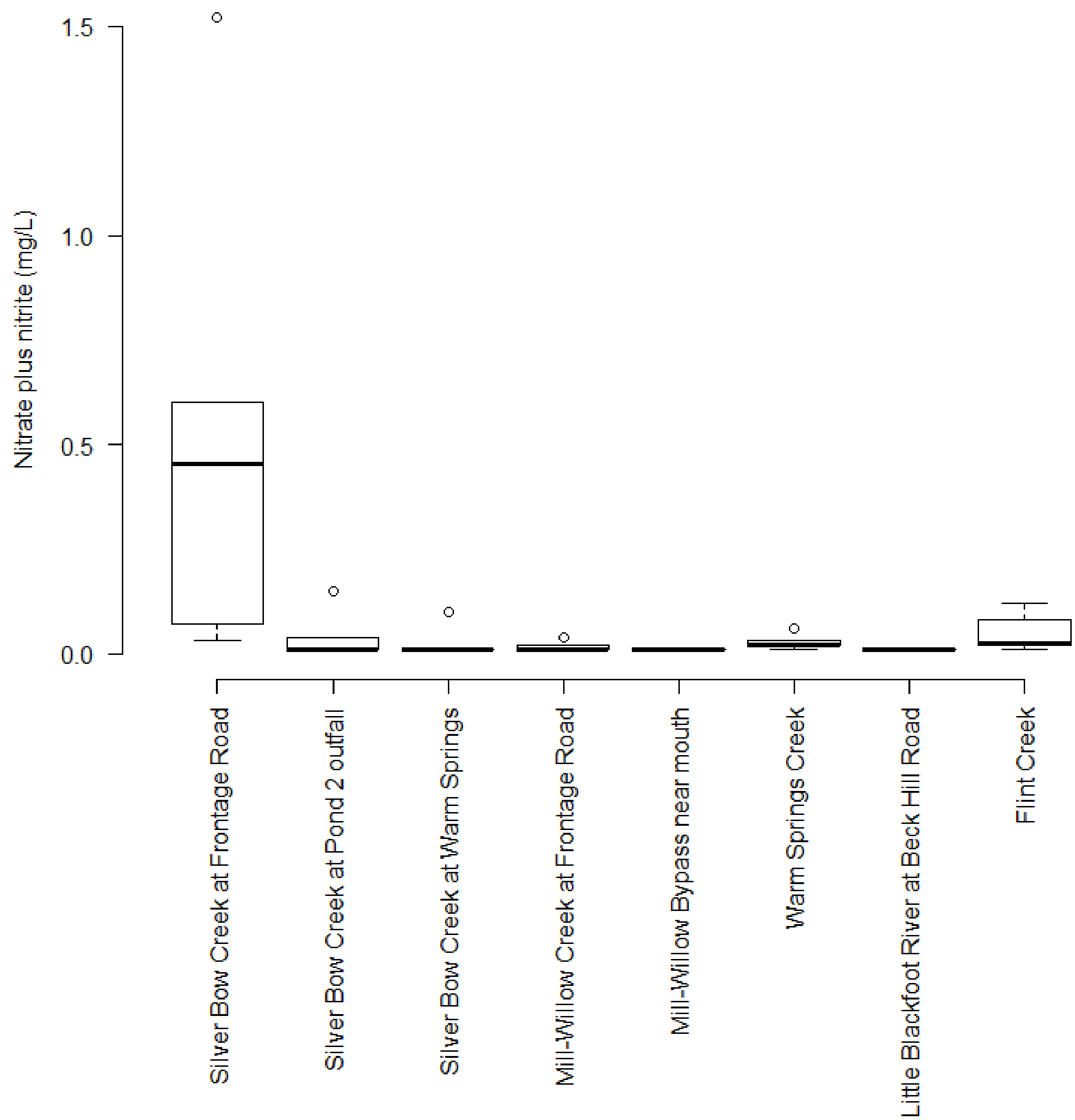

Figure 2-32. Boxplots of nitrate plus nitrite nitrogen concentrations (mg/L) at Clark Fork River tributary monitoring stations, 2017.

2.3.5.3 Total Ammonia

Ammonia concentrations were only measured in the Silver Bow Creek sites in 2017 (SS-19, SBC-P2, and SS-25). All samples had concentrations below the analytical reporting limit (0.05 mg/L).

2.3.5.4 Total Phosphorus

Total phosphorus concentrations in the Clark Fork River mainstem in 2017 ranged from 0.009-0.140 mg/L (Table 2-7). Median total phosphorus concentrations were highest at the Williams-Tavenner Bridge site at river mile 34 (CFR-34) (Figure 2-33). At all sites in the mainstem, median total phosphorus concentrations in 2017 were above the total phosphorus Clark Fork River-specific standard (Figure 2-33) although that standard only technically applied to the Q2-Falling and Q3 samples. All mainstem sites had concentrations exceeding the Clark Fork River-specific standard during the Q2-Falling sample period (Table 2-7). In Q3, only the sample from CFR-34 exceeded the Clark Fork River-specific standard but that sample also exceeded the Middle Rockies Ecoregion-specific standard, as well (Table 2-7).

Total phosphorus concentrations in the Clark Fork River tributaries in 2017 ranged from 0.004-0.183 mg/L (Table 2-7). All Silver Bow Creek samples, except one from the Warm Springs site in Q4, had concentrations exceeding the Middle Rockies Ecoregion-specific standard, although that standard technically only applied during Q3 (Figure 2-34). Median concentrations in Silver Bow Creek above the Warm Springs ponds (at Frontage Road; SS-19) were nearly double the concentrations in Silver Bow Creek immediately below the ponds (at Pond 2 Outfall; SBC-P2) (Figure 2-34). Concentrations in the two Mill-Willow Creek sites were similar (Figure 2-34). In Q3, concentrations in Flint Creek exceeded the Middle Rockies Ecoregion-specific standard (Table 2-7).

Table 2-7. Total phosphorus concentrations (mg/L) at Clark Fork River Operable Unit monitoring stations, 2017.

Site ID	Site Location	Sample Period					
		Q1	Q2			Q3	Q4
			Rising	Peak	Falling		
Mainstem Sites							
CFR-03A	Clark Fork River near Galen	0.025	0.044	0.062	0.024	0.014	0.015
CFR-07D	Clark Fork River at Galen Road	0.019	0.050	0.067	0.026	0.015	0.013
CFR-11F	Clark Fork River at Gemback Road	0.019	0.051	0.062	0.026	0.016	0.012
CFR-27H	Clark Fork River at Deer Lodge	0.026	0.067	0.113	0.031	0.014	0.014
CFR-34	Clark Fork River at Williams-Tavenner Bridge	0.042	0.071	0.140	0.044	0.031	0.019
CFR-116A	Clark Fork River at Turah	0.024	0.048	0.070	0.030	0.009	0.022
Tributary Sites							
SS-19	Silver Bow Creek at Frontage Road	0.118	0.112	0.112	0.113	0.092	0.154
SBC-P2	Silver Bow Creek at Pond 2 outfall	0.052	0.069	0.183	0.106	0.084	0.033
SS-25	Silver Bow Creek at Warm Springs	0.042	0.050	0.091	0.050	0.041	0.025
MCWC-MWB	Mill-Willow Creek at Frontage Road	0.020	0.031	0.030	0.020	0.015	0.025
MWB-SBC	Mill-Willow Bypass near mouth	0.021	0.030	0.026	0.017	0.008	0.012
WSC-SBC	Warm Springs Creek near mouth	0.008	0.012	0.022	0.009	0.005	0.004
LBR-CFR-02	Little Blackfoot River at Beck Hill Road	0.031	0.038	0.045	0.021	0.017	0.020
FC-CFR	Flint Creek near mouth	0.052	0.057	0.063	0.042	0.054	0.025

--- Not sampled.

ND Not detected at analytical reporting limit.

(green) Exceeds the Middle Rockies Ecoregion total phosphorus standard (0.030 mg/L; applies July 1 to September 30; DEQ [2014].

(orange) Exceeds Clark Fork River total phosphorus standard (0.020 mg/L; applies to mainstem sites from June 21 to September 21; ARM 17.30.631).

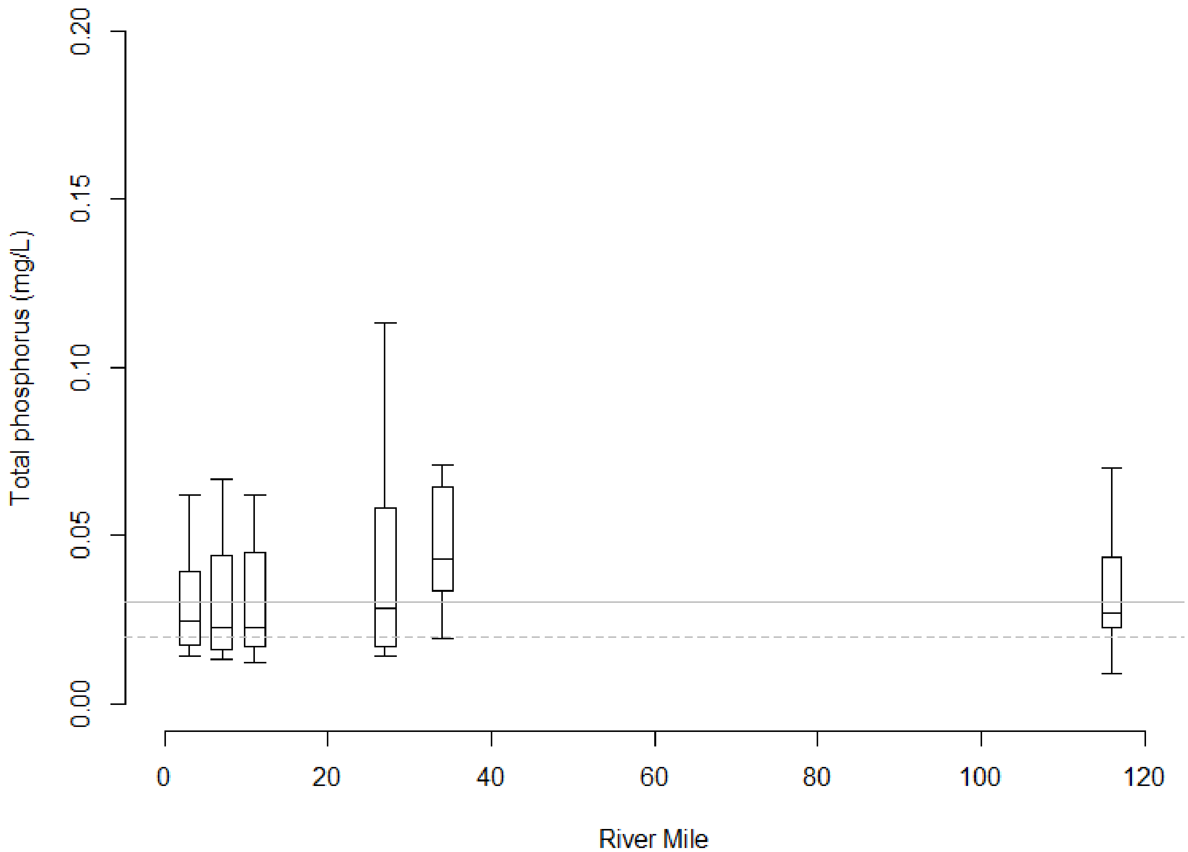

Figure 2-33. Boxplots of total phosphorus concentrations (mg/L) at Clark Fork River mainstem monitoring stations, 2017. Horizontal lines represent standards specific to the Clark Fork River (dashed line; ARM 17.30.631) and the Middle Rockies Ecoregion (solid line; DEQ [2014].

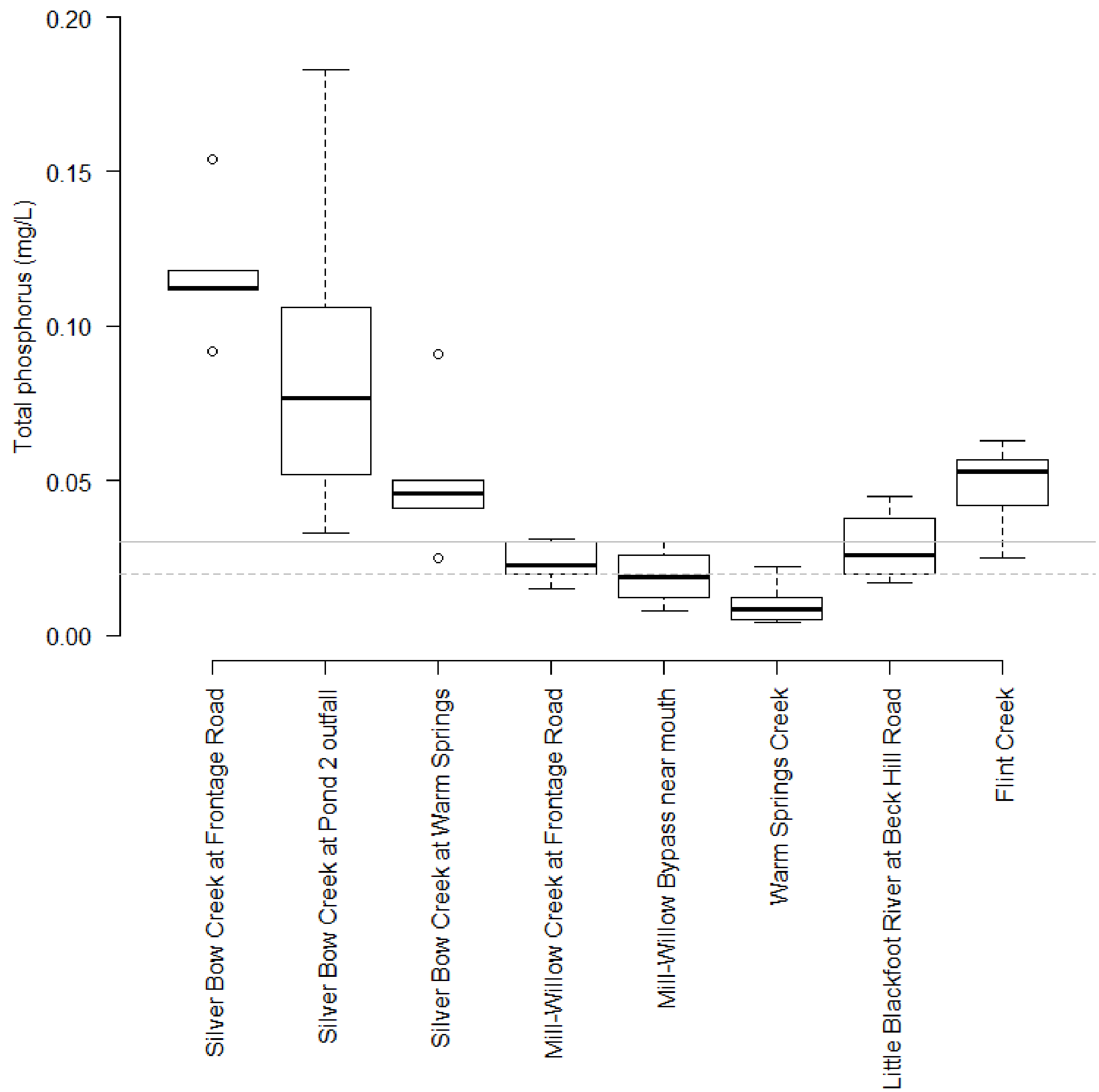

Figure 2-34. Boxplots of total phosphorus concentrations (mg/L) at Clark Fork River tributary monitoring stations, 2017. Horizontal lines represent standards specific to the Clark Fork River (dashed line; ARM 17.30.631) and the Middle Rockies Ecoregion (solid line; DEQ [2014].

2.3.6 Contaminants of Concern

2.3.6.1 Arsenic

In the Clark Fork River mainstem in 2017, dissolved arsenic concentrations ranged from 0.003-0.038 mg/L (Table 2-8) and total recoverable concentrations ranged from 0.004-0.038 mg/L (Table 2-9). Exceedances of the dissolved arsenic performance goal occurred at all Reach A sites (i.e., CFR-03A, CFR-07D, CFR-11F, CFR-27H, and CFR-34) during all Q2 and Q3 sample periods (Table 2-8). Exceedances of the total recoverable arsenic performance goal occurred in all Reach A sites except near Galen (CFR-03A) during the Q2-Rising and Q2-Peak sample periods (Table 2-9). The only site exceeding the total recoverable performance goal during the Q2-Falling sample period was the Williams-Tavenner Bridge site (CFR-34) (Table 2-9). One total recoverable exceedance occurred (at Gemback Road; CFR-11F) in Q3 (Table 2-9).

Longitudinally, in 2017 mainstem Reach A sites (i.e., sites sampled between river mile 3-42) appeared to have substantially higher median arsenic concentrations compared to concentrations at Turah (river mile 116) (Figure 2-35; Figure 2-36). Concentrations tended to increase (and become more variable, with distance downstream through Reach A (Figure 2-35; Figure 2-36).

Dissolved and total recoverable arsenic concentrations at each Clark Fork River mainstem site were generally similar in 2017 compared to prior monitoring years, although total recoverable concentrations at Deer Lodge and the Williams-Tavenner Bridge were somewhat higher than during the past few years (Figure 2-37; Figure 2-38). Over the period of monitoring at these mainstem sites, there do not appear to be any discernable temporal trends at these sites in either dissolved or total recoverable arsenic concentrations given the variability in these data (Figure 2-37; Figure 2-38).

In the Clark Fork River tributaries in 2017, dissolved arsenic concentrations ranged from 0.004-0.019 mg/L (Table 2-8) and total recoverable concentrations ranged from 0.005-0.039 mg/L (Table 2-9). Exceedances of the dissolved and total recoverable arsenic performance goals occurred in both Silver Bow Creek sites located downstream from the Warm Springs Ponds (i.e., SBC-P2 and SS-25) during all Q2 and Q3 sample periods (Table 2-8; Table 2-9). Exceedances of the dissolved arsenic performance goal occurred in both Mill-Willow Creek sites (MCWC-MWB and MWB-SBC) during all sample periods (Table 2-8). Exceedances of the total recoverable performance goal occurred in both Mill-Willow Creek sites in all three Q2 sample periods as well as at Frontage Road (MCWC-MWB) in Q4 and near the confluence (MWB-SBC) in Q3 (Table 2-9).

Median dissolved and total recoverable arsenic concentrations increased by more than double between paired sites in Silver Bow Creek above (SS-19) and below (SBC-P2) the Warm Springs Ponds (Figure 2-39; Figure 2-40). Between paired Mill-Willow Creek sites above (MCWC-MWB) and below (MWB-SBC) the Mill-Willow Bypass, median dissolved and total recoverable arsenic concentrations were similar (Figure 2-39; Figure 2-40). The Silver Bow Creek sites below the Warm Springs Ponds (SBC-P2 and SS-25) and the two Mill-Willow Creek sites had the highest median arsenic concentrations of any tributary sites by a substantial margin (Figure 2-39; Figure

2-40). The lowest median arsenic concentrations occurred in Warm Springs Creek and the Little Blackfoot River (Figure 2-39; Figure 2-40).

Dissolved and total recoverable arsenic concentrations at each Clark Fork River tributary sites were similar in 2017 compared to prior monitoring years (Figure 2-41; Figure 2-42). Over the period of monitoring at these tributary sites, there do not appear to be any temporal trends at any of these sites in either dissolved or total recoverable arsenic concentrations given the variability in these data (Figure 2-41; Figure 2-42).

Table 2-8. Dissolved arsenic concentrations (mg/L) at Clark Fork River Operable Unit monitoring stations, 2017.

Site ID	Site Location	Sample Period					
		Q1	Q2			Q3	Q4
			Rising	Peak	Falling		
Mainstem Sites							
CFR-03A	Clark Fork River near Galen	0.007	0.015	0.014	0.013	0.015	0.007
CFR-07D	Clark Fork River at Galen Road	0.008	0.016	0.015	0.013	0.015	0.008
CFR-11F	Clark Fork River at Gemback Road	0.008	0.016	0.016	0.014	0.019	0.008
CFR-27H	Clark Fork River at Deer Lodge	0.008	0.015	0.017	0.015	0.014	0.008
CFR-34	Clark Fork River at Williams-Tavenner Bridge	0.009	0.016	0.018	0.017	0.016	0.009
CFR-116A	Clark Fork River at Turah	0.005	0.004	0.007	0.007	0.006	0.005
Tributary Sites							
SS-19	Silver Bow Creek at Frontage Road	0.005	0.006	0.006	0.008	0.008	0.005
SBC-P2	Silver Bow Creek at Pond 2 Outfall	0.009	0.020	0.019	0.021	0.038	0.007
SS-25	Silver Bow Creek at Warm Springs	0.010	0.019	0.022	0.021	0.027	0.010
MCWC-MWB	Mill-Willow Creek at Frontage Road	0.011	0.018	0.024	0.022	0.016	0.016
MWB-SBC	Mill-Willow Bypass near mouth	0.011	0.017	0.024	0.022	0.020	0.016
WSC-SBC	Warm Springs Creek near mouth	0.004	0.004	0.005	0.005	0.005	0.003
LBR-CFR-02	Little Blackfoot River at Beck Hill Road	0.004	0.005	0.006	0.005	0.005	0.004
FC-CFR	Flint Creek near mouth	0.006	0.005	0.008	0.010	0.010	0.005

--- Not sampled.

Exceeds specified arsenic surface water performance goal for dissolved concentration (0.010 mg/L) [USEPA, 2004].

Table 2-9. **Total recoverable arsenic concentrations (mg/L) at Clark Fork River Operable Unit monitoring stations, 2017.**

Site ID	Site Location	Sample Period					
		Q1	Q2			Q3	Q4
			Rising	Peak	Falling		
Mainstem Sites							
CFR-03A	Clark Fork River near Galen	0.009	0.017	0.017	0.013	0.014	0.009
CFR-07D	Clark Fork River at Galen Road	0.009	0.020	0.021	0.014	0.015	0.009
CFR-11F	Clark Fork River at Gemback Road	0.010	0.021	0.022	0.016	0.019	0.010
CFR-27H	Clark Fork River at Deer Lodge	0.012	0.028	0.035	0.017	0.014[J]	0.014
CFR-34	Clark Fork River at Williams-Tavenner Bridge	0.013	0.027	0.039	0.023	0.016[J]	0.012
CFR-116A	Clark Fork River at Turah	0.007	0.007	0.013	0.008	0.005	0.006
Tributary Sites							
SS-19	Silver Bow Creek at Frontage Road	0.006	0.007	0.008	0.008	0.008	0.005
SBC-P2	Silver Bow Creek at Pond 2 Outfall	0.010	0.020	0.020	0.021	0.038	0.010
SS-25	Silver Bow Creek at Warm Springs	0.012	0.021	0.023	0.022	0.029	0.012
MCWC-MWB	Mill-Willow Creek at Frontage Road	0.013	0.020	0.026	0.024	0.017	0.019
MWB-SBC	Mill-Willow Bypass near mouth	0.015	0.020	0.027	0.023	0.021	0.018
WSC-SBC	Warm Springs Creek near mouth	0.004	0.005	0.008	0.006	0.005	0.006
LBR-CFR-02	Little Blackfoot River at Beck Hill Road	0.004	0.006	0.006	0.005	0.005	0.005
FC-CFR	Flint Creek near mouth	0.009	0.011	0.016	0.016	0.018	0.007

--- Not sampled.

(red) Exceeds specified arsenic surface water performance goal for total recoverable concentration (0.018 mg/L) [USEPA, 2004].

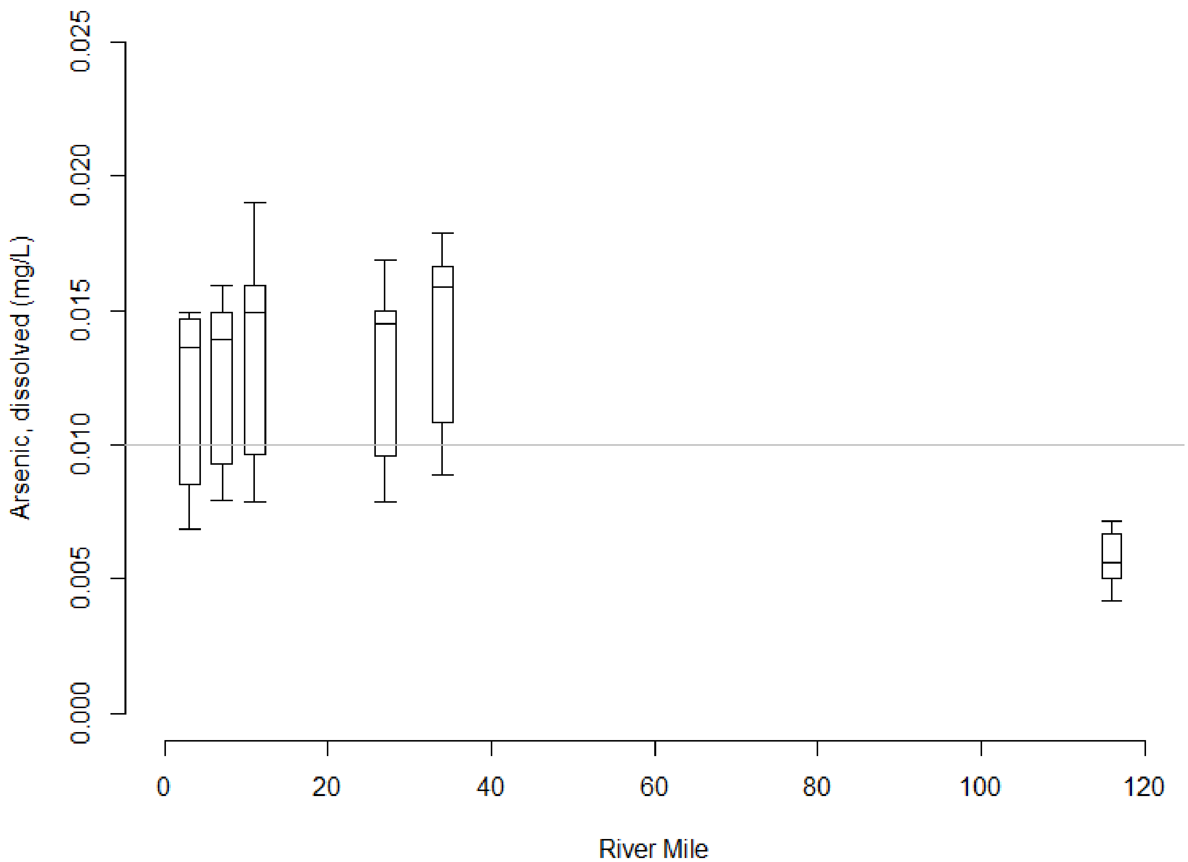

Figure 2-35. Boxplots of dissolved arsenic concentration by river mile at mainstem sampling sites in the Clark Fork River Operable Unit, 2017. Horizontal line represents the arsenic performance goal for dissolved concentration [USEPA, 2004].

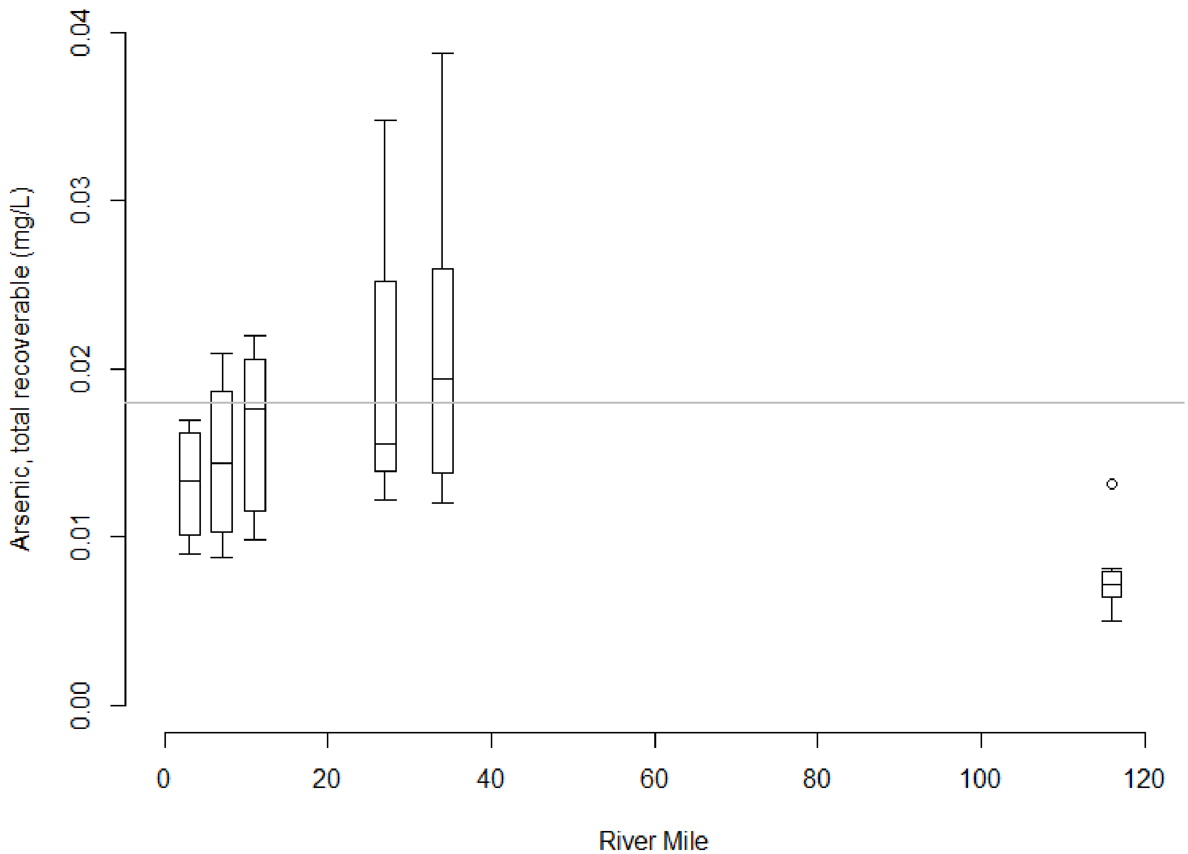

Figure 2-36. Boxplots of total recoverable arsenic concentrations by river mile at mainstem sampling sites in the Clark Fork River Operable Unit, 2017. Horizontal line represents the arsenic performance goal for total recoverable concentration [USEPA, 2004].

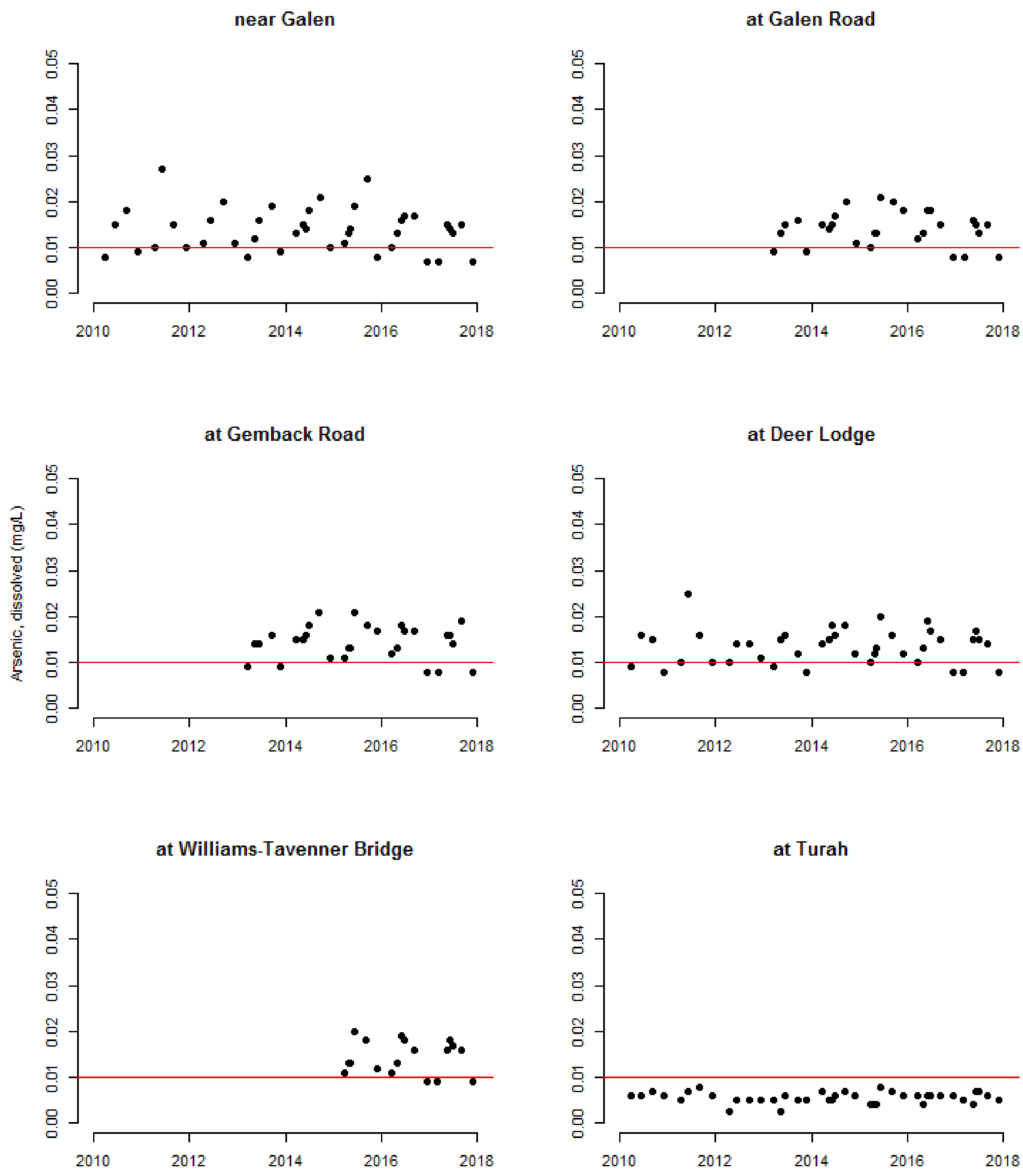

Figure 2-37. Dissolved arsenic concentrations at mainstem sampling sites in the Clark Fork River Operable Unit, 2010-2017. Horizontal lines represent the arsenic performance goal for dissolved concentration [USEPA, 2004].

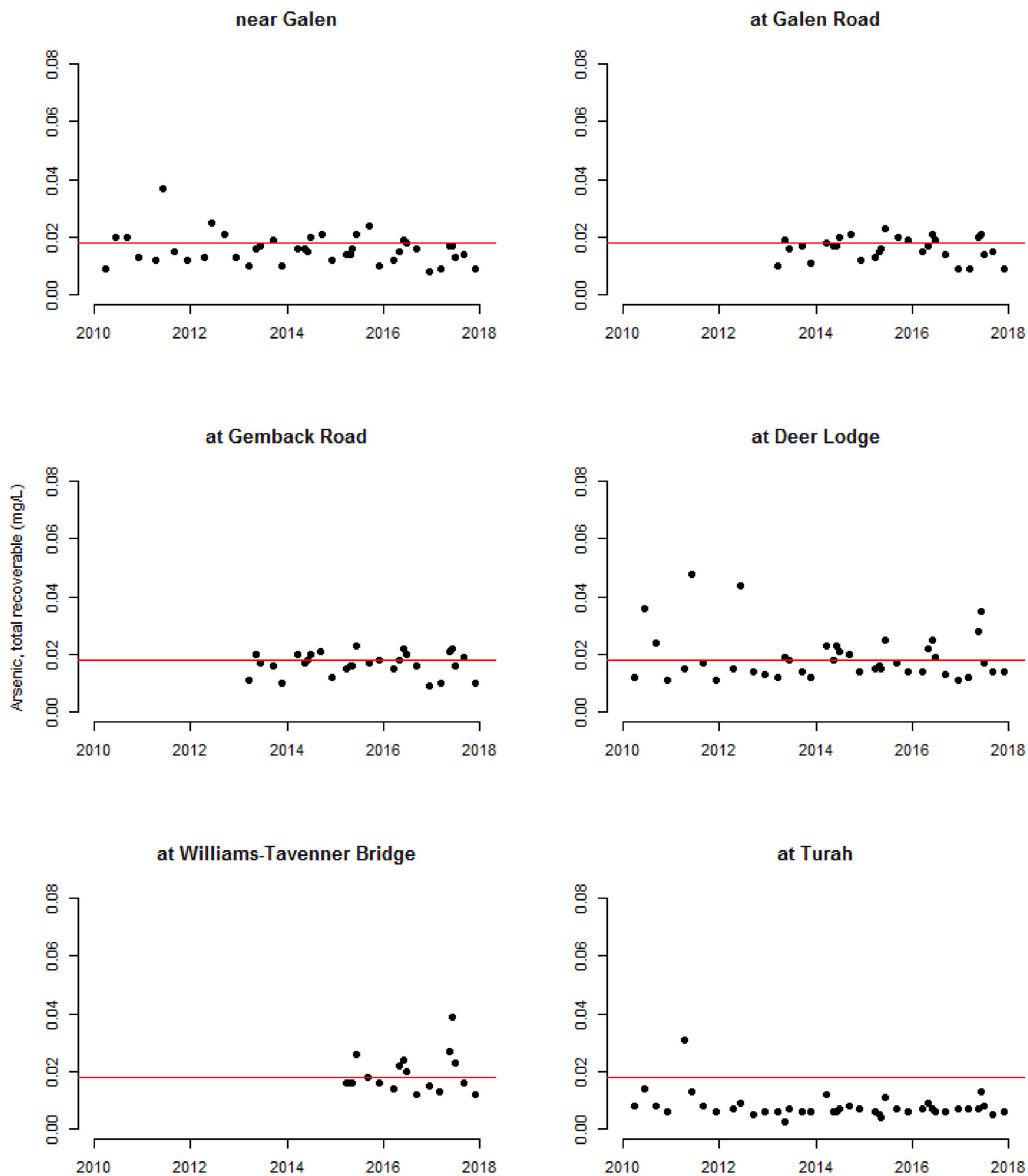

Figure 2-38. Total recoverable arsenic concentrations at mainstem sampling sites in the Clark Fork River Operable Unit, 2010-2017. Horizontal lines represent the arsenic performance goal for total recoverable concentration [USEPA, 2004].

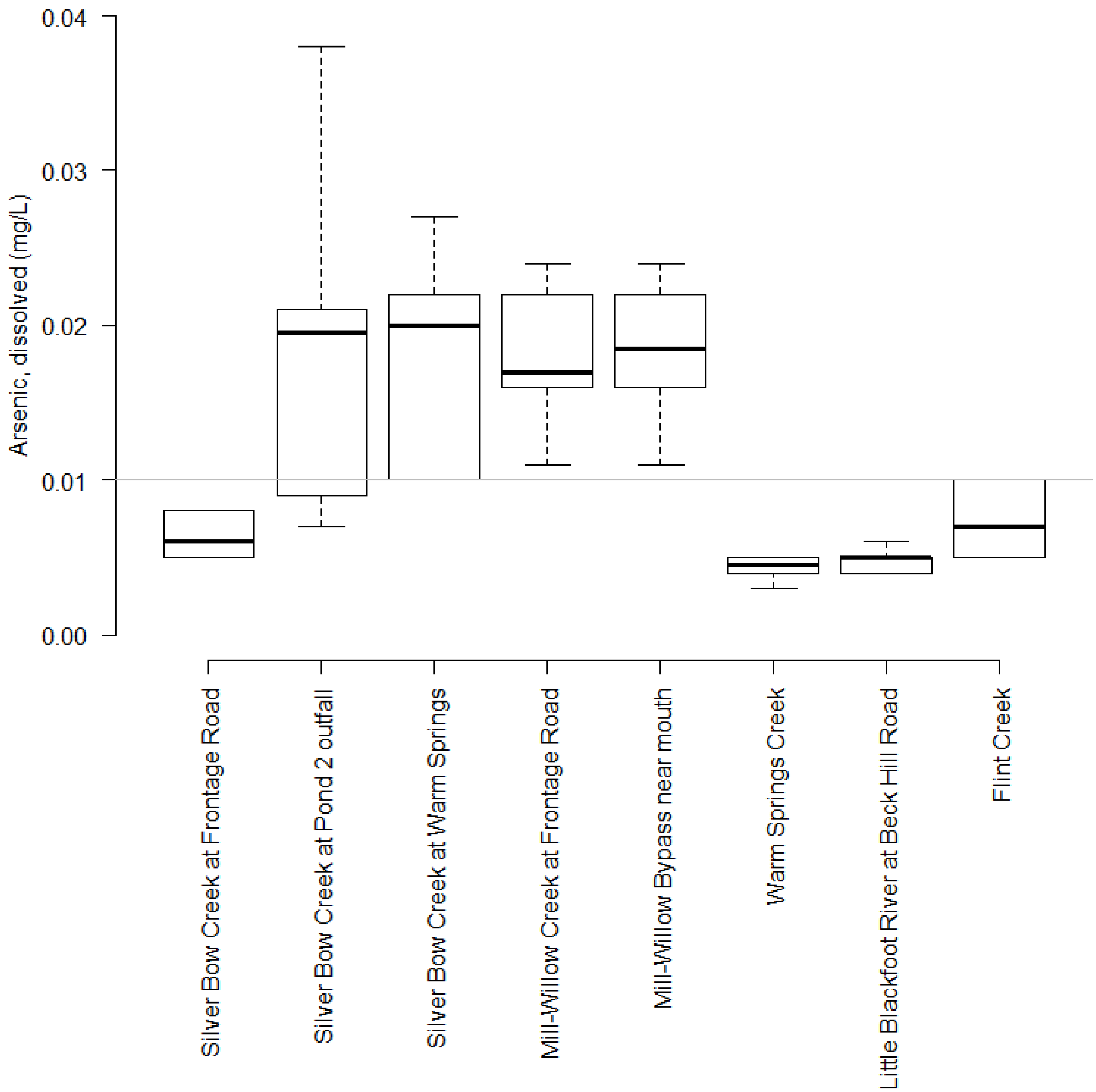

Figure 2-39. Boxplots of dissolved arsenic concentrations at tributary sampling sites in the Clark Fork River Operable Unit, 2017. Horizontal line represents the arsenic performance goal for dissolved concentration [USEPA, 2004].

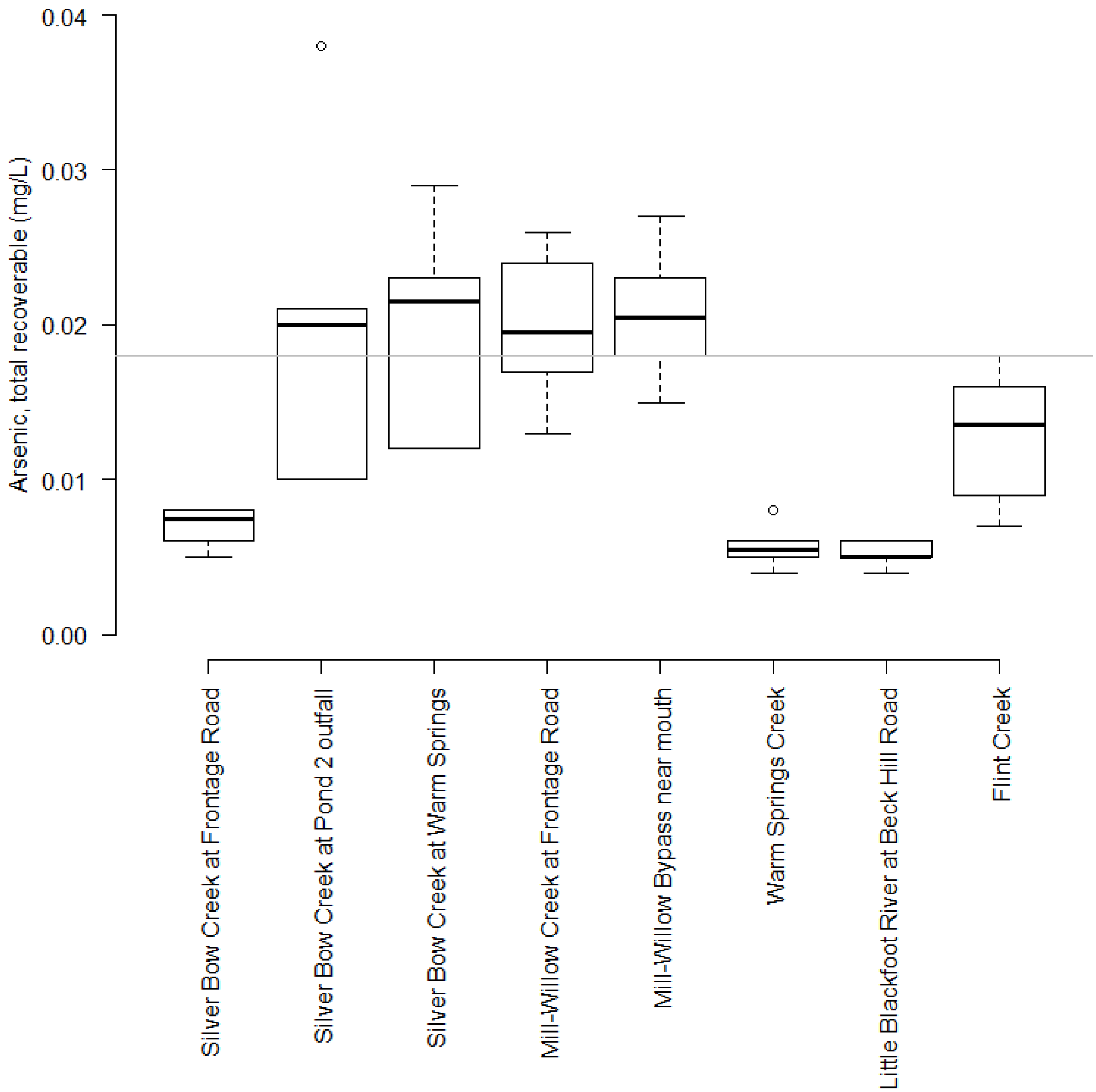

Figure 2-40. Boxplots of total recoverable arsenic concentrations at tributary sampling sites in the Clark Fork River Operable Unit, 2017. Horizontal line represents the arsenic performance goal for total recoverable concentration [USEPA, 2004].

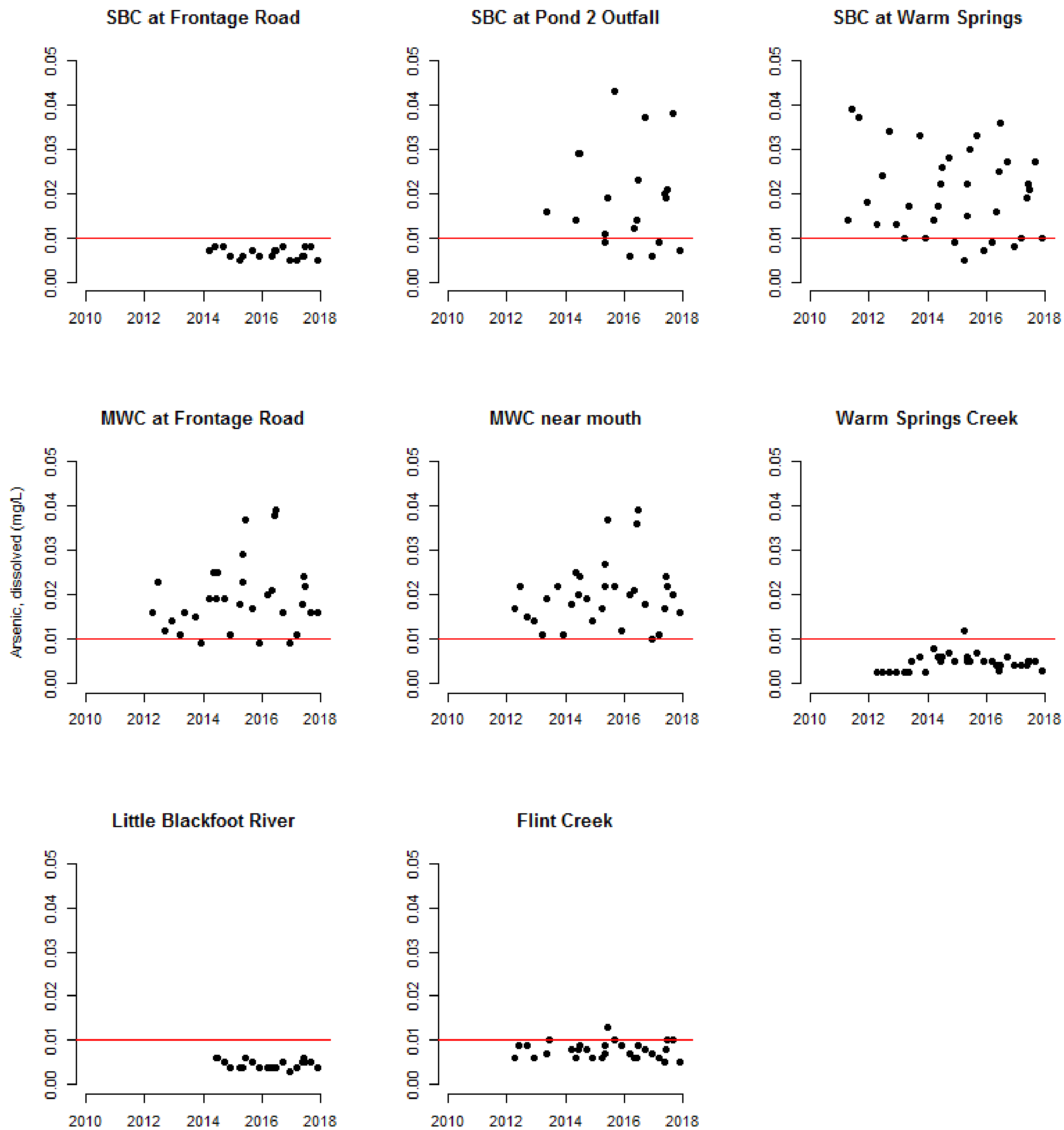

Figure 2-41. Dissolved arsenic concentrations at tributary sampling sites[13] in the Clark Fork River Operable Unit, 2010-2017. Horizontal line represents the arsenic performance goal for dissolved concentration [USEPA, 2004].

[13] Tributary abbreviations: SBC = Silver Bow Creek and MWC = Mill-Willow Creek.

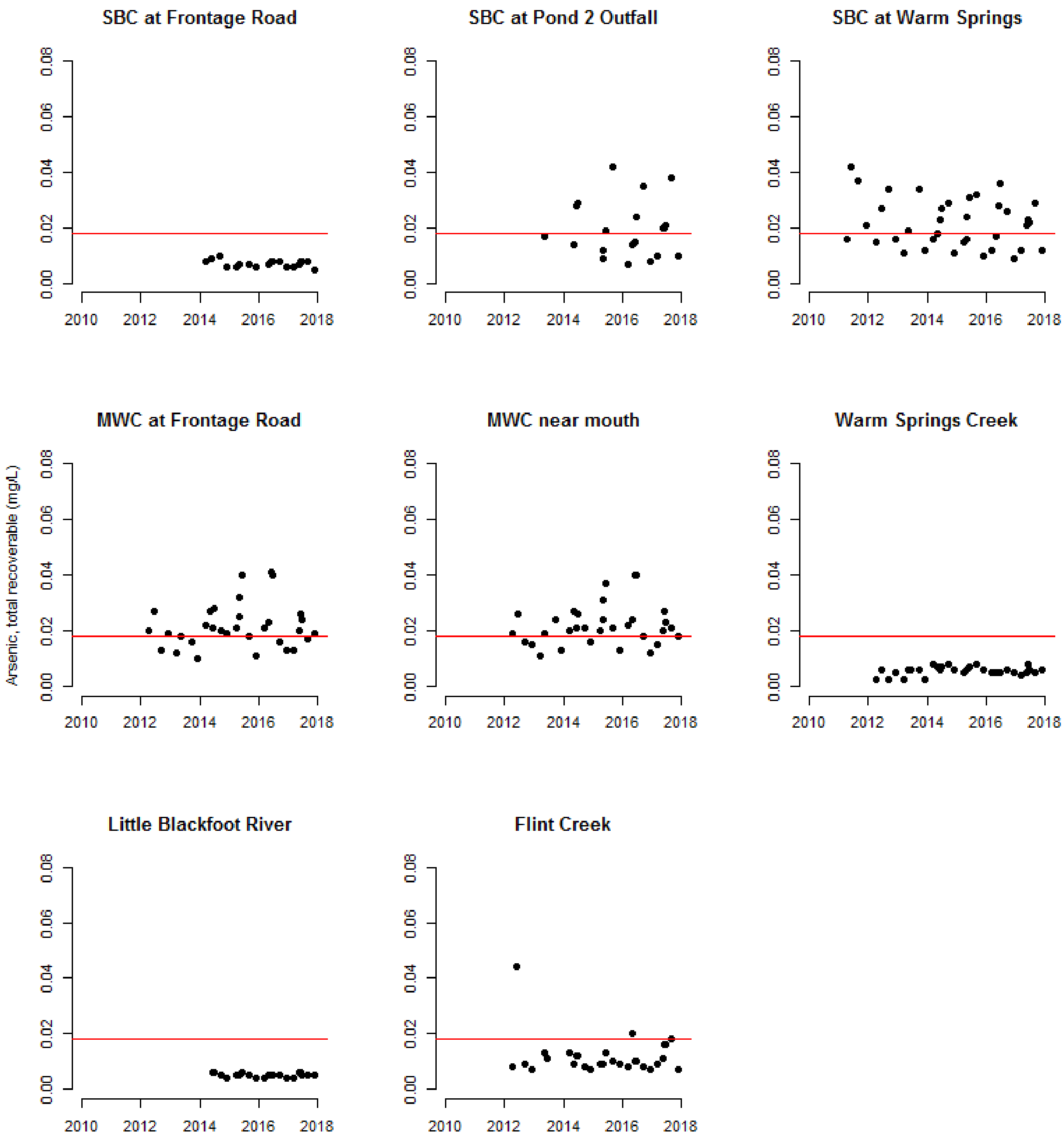

Figure 2-42. Total recoverable arsenic concentrations at tributary sampling sites[14] in the Clark Fork River Operable Unit, 2010-2017. Horizontal line represents the arsenic performance goal for total recoverable concentration [USEPA, 2004].

[14] Tributary abbreviations: SBC = Silver Bow Creek and MWC = Mill-Willow Creek.

2.3.6.2 Cadmium

In the Clark Fork River mainstem in 2017, total recoverable cadmium concentrations ranged from <0.00003-0.00201 mg/L (Table 2-10). The maximum concentration observed in the mainstem in 2017 was more than twice as high as any previous mainstem concentration since monitoring began in 2010. Exceedances of the chronic aquatic life standard occurred in the mainstem for cadmium at Deer Lodge (CFR-27H) in Q4 and at Williams-Tavenner Bridge (CFR-34) during the Q2-Peak monitoring period (Table 2-10). However, the sample concentration from CFR-34 during the Q2-Peak monitoring period was estimated because the associated field duplicate pair for total recoverable cadmium samples collected on that day failed the data quality objective for sampling precision (Table 2-10; Appendix A).

Longitudinally, median total recoverable cadmium concentrations at mainstem sites increased through Reach A from river mile 3 (Clark Fork River near Galen; CFR-03A) to river mile 27 (Clark Fork River at Deer Lodge; CFR-27H) and then decreased downstream to river mile 116 (Clark Fork River at Turah; CFR-116A) in 2017 (Figure 2-43).

Total recoverable cadmium concentrations at each Clark Fork River mainstem site were generally similar in 2017 compared to prior monitoring years although there were several notable exceptions where 2017 samples had concentrations that were higher than expected compared to prior monitoring years (Figure 2-44). Over the period of monitoring at these mainstem sites, there do not appear to be any temporal trends at these sites in total recoverable cadmium concentrations given the variability in these data (Figure 2-44).

In the Clark Fork River tributaries in 2017, total recoverable cadmium concentrations ranged from <0.00003-0.00388 mg/L (Table 2-10). The maximum concentration observed in Flint Creek (0.00388 mg/L) in 2017 was the highest concentration among all CFROU sites since monitoring began in 2010. That sample concentration exceeded the chronic aquatic life standard, but it was an estimated concentration because the associated field duplicate pair for total recoverable cadmium samples collected on that day failed the data quality objective for sampling precision (Table 2-10; Appendix A).

Median total recoverable cadmium concentrations decreased, by about half, between paired sites in Silver Bow Creek above (SS-19) and below (SBC-P2) the Warm Springs Ponds (Figure 2-45). Between paired Mill-Willow Creek sites above (MCWC-MWB) and below (MWB-SBC) the Mill-Willow Bypass, median concentrations decreased slightly at the downstream site (Figure 2-45). Although Flint Creek and Warm Springs Creek sites each had one anomalously high sample concentration in 2017, median concentrations at each site were low compared to the chronic aquatic life standard (Figure 2-45).

Generally, total recoverable cadmium concentrations at each Clark Fork River tributary site were similar in 2017 compared to prior monitoring years with a few exceptions (Figure 2-46). Warm Springs Creek, Flint Creek, and the Little Blackfoot River each had samples with substantially higher concentrations than in any prior monitoring period (Figure 2-46). Temporal trends are not apparent at most tributary sites except for Silver Bow Creek at Frontage Road (SS-

19) (Figure 2-46). Based on the distribution of the sample concentrations at SS-19, it appears that mean concentrations are steadily decreasing (Figure 2-46).

Table 2-10. Total recoverable cadmium concentrations (mg/L) at Clark Fork River Operable Unit monitoring stations, 2017.

Site ID	Site Location	Sample Period					
		Q1	Q2			Q3	Q4
			Rising	Peak	Falling		
Mainstem Sites							
CFR-03A	Clark Fork River near Galen	0.00007	0.00012	0.00015	0.00006	ND	0.00013
CFR-07D	Clark Fork River at Galen Road	0.00008	0.00018	0.00030	0.00008	0.00003	0.00008
CFR-11F	Clark Fork River at Gemback Road	0.00008	0.00022	0.00027	0.00007	0.00004	0.00015
CFR-27H	Clark Fork River at Deer Lodge	0.00019	0.00040	0.00060	0.00013	0.00006	0.00201
CFR-34	Clark Fork River at Williams-Tavenner Bridge	0.00026	0.00046	0.00088	0.00021	0.00009	0.00031
CFR-116A	Clark Fork River at Turah	0.00009	0.00014	0.00042	0.00007	ND	0.00006
Tributary Sites							
SS-19	Silver Bow Creek at Frontage Road	0.00043	0.00024	0.00024	0.00017	0.00025	0.00043
SBC-P2	Silver Bow Creek at Pond 2 Outfall	0.00010	0.00010	0.00022	0.00008	ND	0.00015
SS-25	Silver Bow Creek at Warm Springs	0.00010	0.00012	0.00016	0.00008	ND	0.00011
MCWC-MWB	Mill-Willow Creek at Frontage Road	0.00009	0.00011	0.00014	0.00008	0.00005	0.00040
MWB-SBC	Mill-Willow Bypass near mouth	0.00007	0.00012	0.00010	0.00006	ND	0.00004
WSC-SBC	Warm Springs Creek near mouth	0.00005	0.00005	0.00013	0.00005	0.00004	0.00084
LBR-CFR-02	Little Blackfoot River at Beck Hill Road	ND	0.00004	0.00024	ND	ND	0.00040
FC-CFR	Flint Creek near mouth	0.00005	0.00007	0.00025	0.00008	0.00388	0.00033

--- Not sampled.

ND Not detected at analytical reporting limit.

Exceeds chronic aquatic life standard [DEQ, 2017].

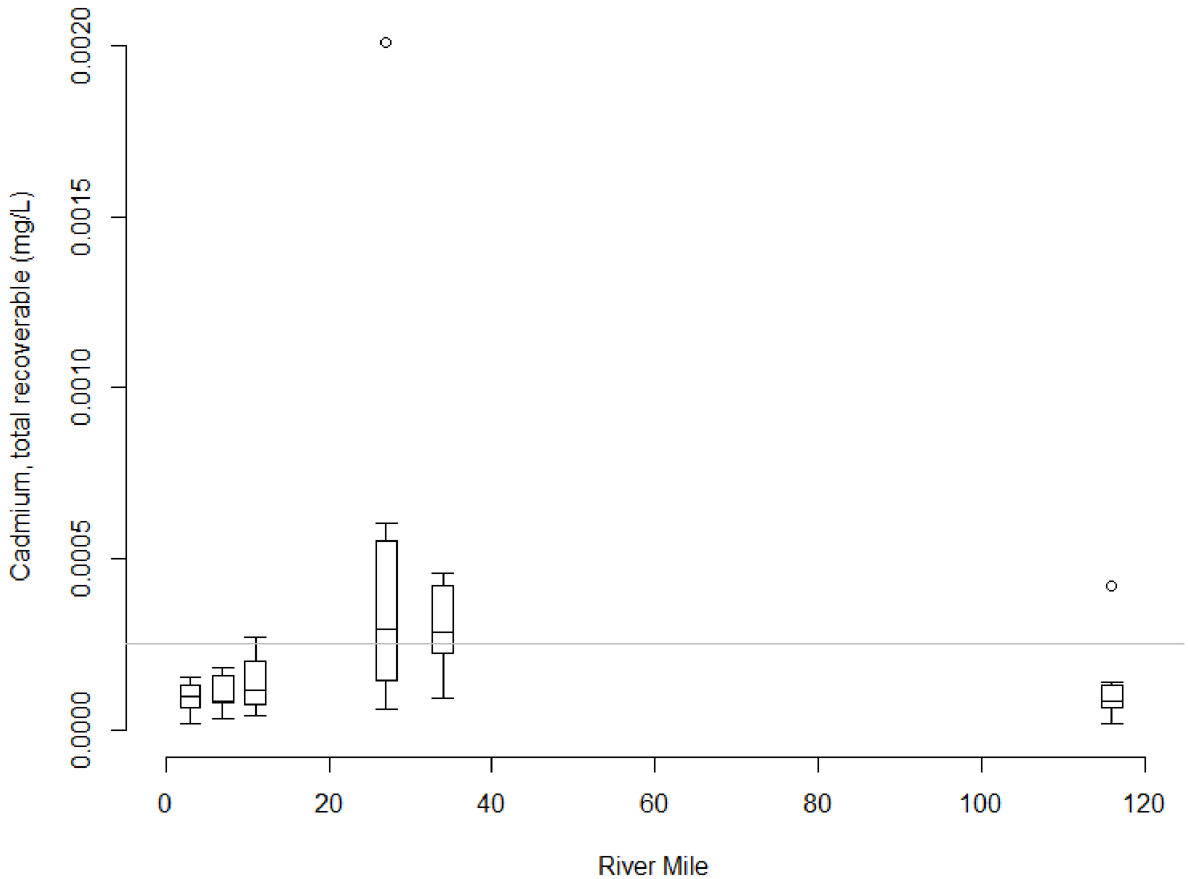

Figure 2-43. Boxplots of total recoverable cadmium concentration by river mile at mainstem sampling sites in the Clark Fork River Operable Unit, 2017. Horizontal line represents the arsenic performance goal for dissolved concentration [USEPA, 2004].

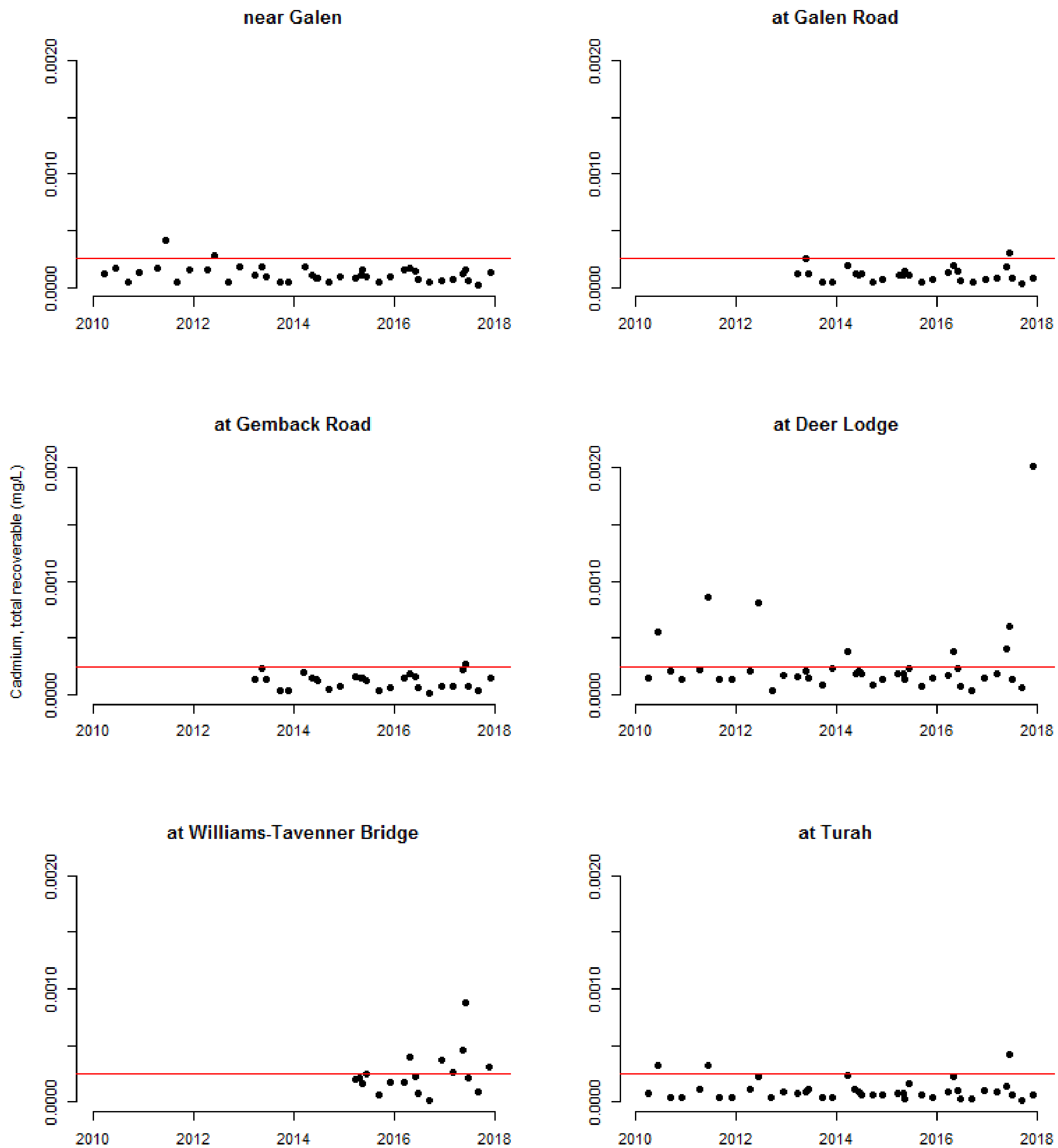

Figure 2-44. Total recoverable cadmium concentrations at mainstem sampling sites in the Clark Fork River Operable Unit, 2010-2017. Horizontal lines represent the arsenic performance goal for dissolved concentration [USEPA, 2004].

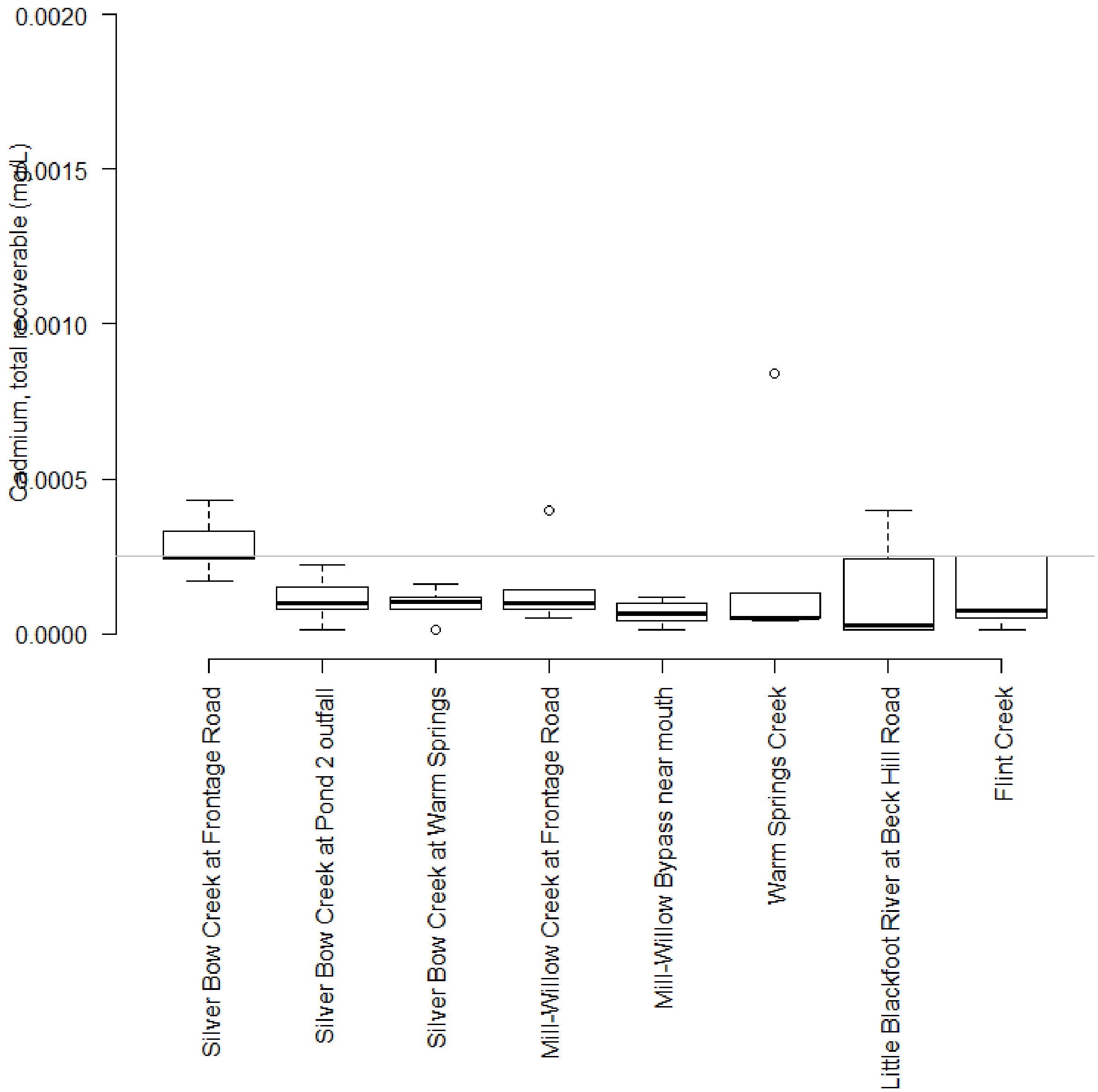

Figure 2-45. Boxplots of total recoverable cadmium concentration at tributary sampling sites in the Clark Fork River Operable Unit, 2017.[15] Horizontal line represents the arsenic performance goal for dissolved concentration [USEPA, 2004].

[15] One sample collected from Flint Creek on September 5, 2017 with an estimated concentration of 0.00388 mg/L is not depected in this figure.

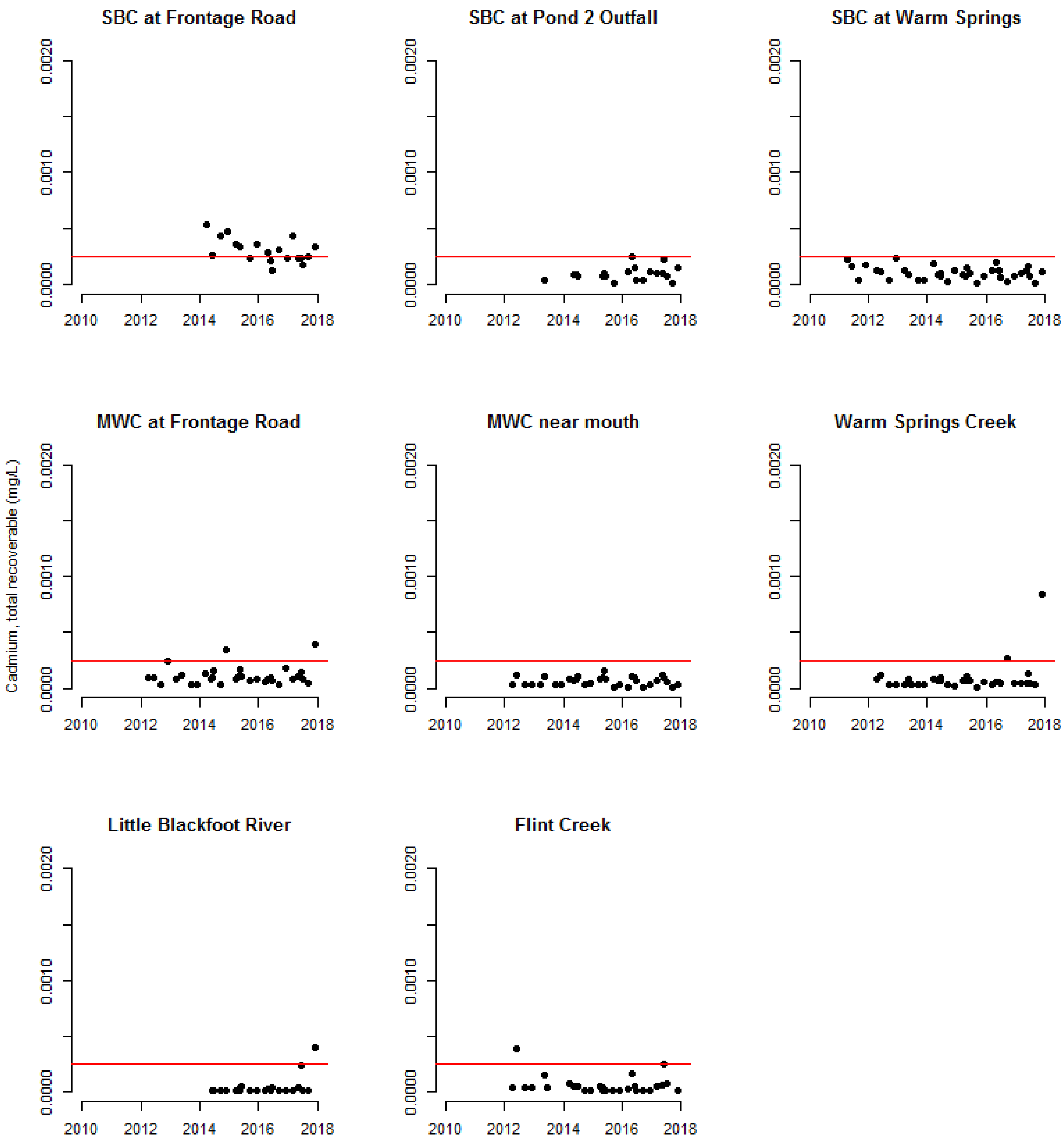

Figure 2-46. Total recoverable cadmium concentrations at tributary sampling sites[16] in the Clark Fork River Operable Unit, 2010-2017[17]. Horizontal lines represent the arsenic performance goal for dissolved concentration [USEPA, 2004].

[16] Tributary abbreviations: SBC = Silver Bow Creek and MWC = Mill-Willow Creek.

2.3.6.3 Copper

In the Clark Fork River mainstem in 2017, dissolved copper concentrations ranged from 0.002-0.018 mg/L (Table 2-11). Two mainstem samples in 2017 had concentrations exceeding the copper performance goal: Clark Fork River at Deer Lodge (CFR-27H) and Clark Fork River at Williams-Tavenner Bridge (CFR-34) during the Q2-Peak sample period (Table 2-11).

Longitudinally, median concentrations at mainstem sites increased gradually through Reach A from river mile 3 (Clark Fork River near Galen; CFR-03A) to river mile 34 (Clark Fork River at Williams-Tavenner Bridge; CFR-34) and then decreased downstream to river mile 116 (Clark Fork River at Turah; CFR-116A) in 2017 (Figure 2-47).

Dissolved copper concentrations at each Clark Fork River mainstem site were generally similar in 2017 compared to prior monitoring years (Figure 2-48). Over the period of monitoring at the mainstem sites, there do not appear to be any temporal trends at these sites given the variability in these data (Figure 2-48).

In the Clark Fork River tributaries in 2017, dissolved copper concentrations ranged from <0.001-0.015 mg/L (Table 2-11). One exceedance of the dissolved copper performance goal occurred in the Clark Fork River tributaries in 2017: in Silver Bow Creek at Frontage Road during the Q2-Falling sample period (Table 2-11).

Median dissolved copper concentrations decreased between paired Silver Bow Creek sites above (SS-19) and below (SBC-P2) the Warm Springs Ponds (Figure 2-49). Between paired Mill-Willow Creek sites above (MCWC-MWB) and below (MWB-SBC) the Mill-Willow Bypass, median concentrations were similar (Figure 2-49). Median concentrations in the Little Blackfoot River and Flint Creek were lower than in the other tributaries (Figure 2-49).

Dissolved copper concentrations at each Clark Fork River tributary site were similar in 2017 compared to prior monitoring years (Figure 2-50). No sites demonstrated clear temporal trends (Figure 2-50).

[17] One sample collected from Flint Creek on September 5, 2017 with an estimated concentration of 0.00388 mg/L is not depected in this figure.

Table 2-11. Dissolved copper concentrations (mg/L) at Clark Fork River Operable Unit monitoring stations, 2017.

Site ID	Site Location	Sample Period					
		Q1	Q2			Q3	Q4
			Rising	Peak	Falling		
Mainstem Sites							
CFR-03A	Clark Fork River near Galen	0.004	0.005	0.007	0.005	0.004	0.003
CFR-07D	Clark Fork River at Galen Road	0.004	0.006	0.009	0.006	0.006	0.003
CFR-11F	Clark Fork River at Gemback Road	0.004	0.006	0.009	0.006	0.007	0.004
CFR-27H	Clark Fork River at Deer Lodge	0.006	0.011	0.016	0.010	0.009	0.006
CFR-34	Clark Fork River at Williams-Tavenner Bridge	0.006	0.011	0.018	0.012	0.008	0.006
CFR-116A	Clark Fork River at Turah	0.003	0.004	0.007	0.004	0.002	0.003
Tributary Sites							
SS-19	Silver Bow Creek at Frontage Road	0.012	0.010	0.008	0.015	0.010	0.008
SBC-P2	Silver Bow Creek at Pond 2 Outfall	0.007	0.008	0.010	0.009	0.003	0.003
SS-25	Silver Bow Creek at Warm Springs	0.005	0.006	0.007	0.005	0.002	0.003
MCWC-MWB	Mill-Willow Creek at Frontage Road	0.001	0.004	0.004	0.003	0.002	0.003
MWB-SBC	Mill-Willow Bypass near mouth	0.001	0.004	0.004	0.003	0.002	0.002
WSC-SBC	Warm Springs Creek near mouth	0.002	0.004	0.005	0.003	0.002	0.002
LBR-CFR-02	Little Blackfoot River at Beck Hill Road	ND	0.001	0.001	ND	ND	ND
FC-CFR	Flint Creek near mouth	0.012	0.002	0.001	0.001	0.010	0.008

--- Not sampled.

ND Not detected at analytical reporting limit.

(yellow highlight) Exceeds federal ambient water quality criteria for chronic toxicity [USEPA, 1986].

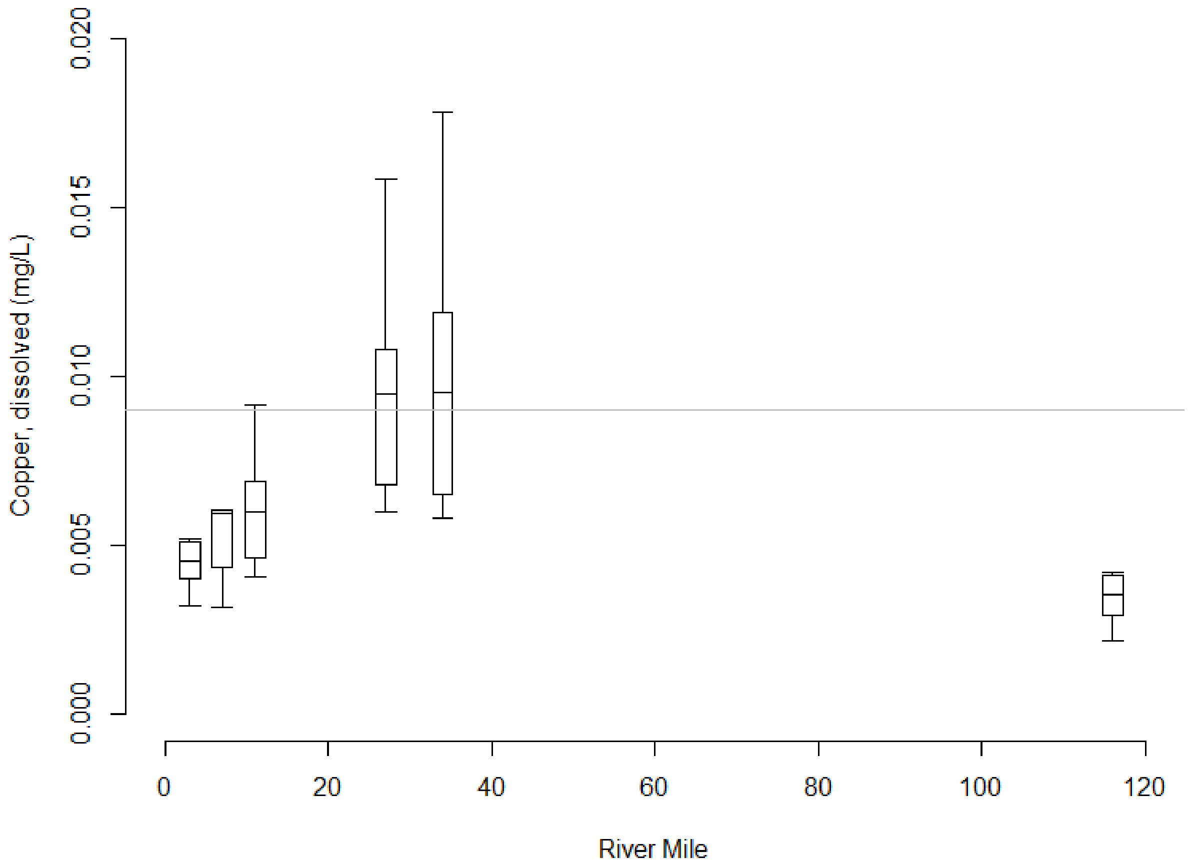

Figure 2-47. Boxplots of dissolved copper concentration by river mile at mainstem sampling sites in the Clark Fork River Operable Unit, 2017. Horizontal line represents the performance goal[18] [USEPA, 2004].

[18] Assuming water hardness is 100 mg/L as CaCO3.

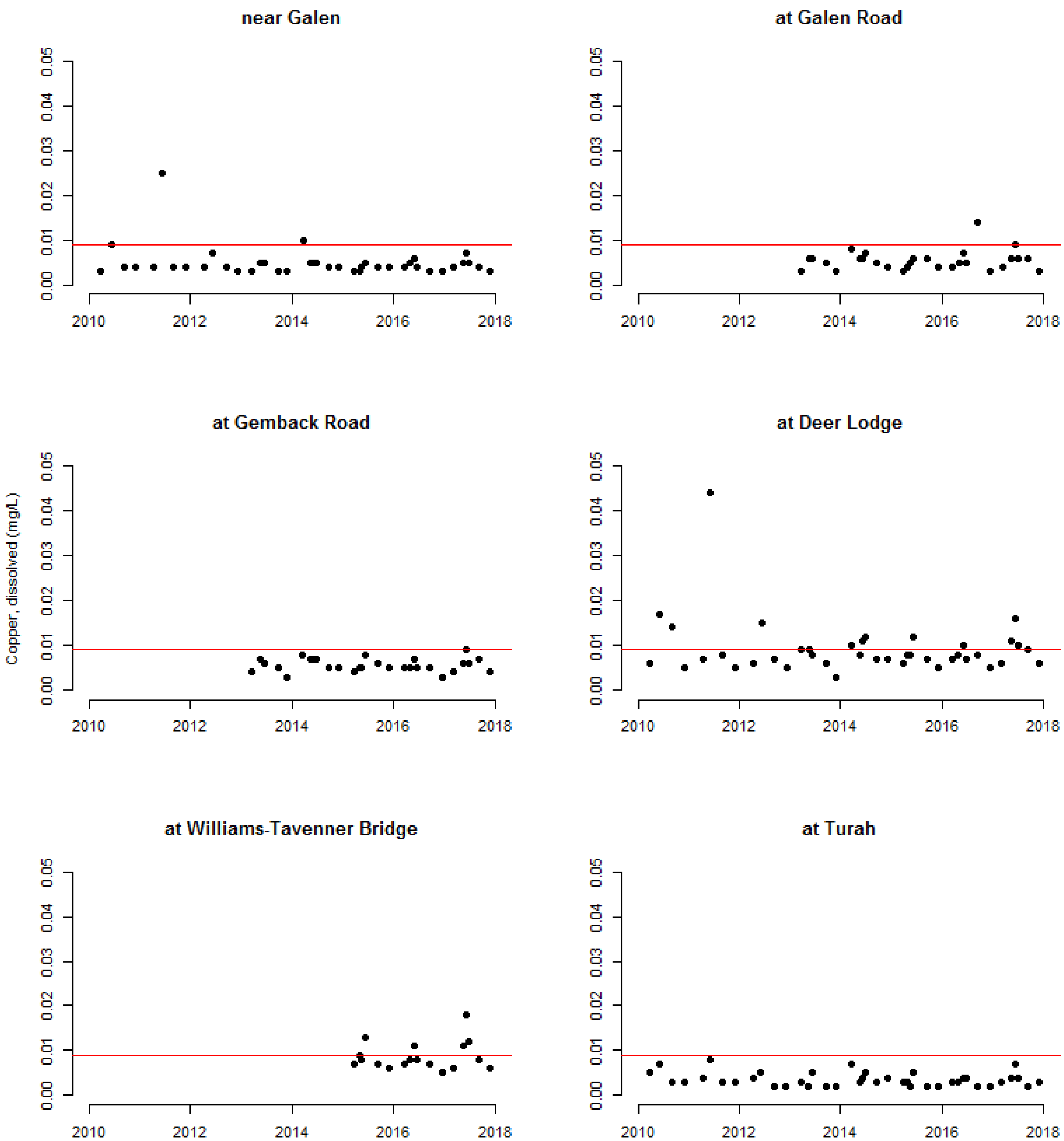

Figure 2-48. Dissolved copper concentrations at mainstem sampling sites in the Clark Fork River Operable Unit, 2010-2017. Horizontal lines represent the performance goal[19] [USEPA, 2004].

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[19] Assuming water hardness is 100 mg/L as CaCO3.

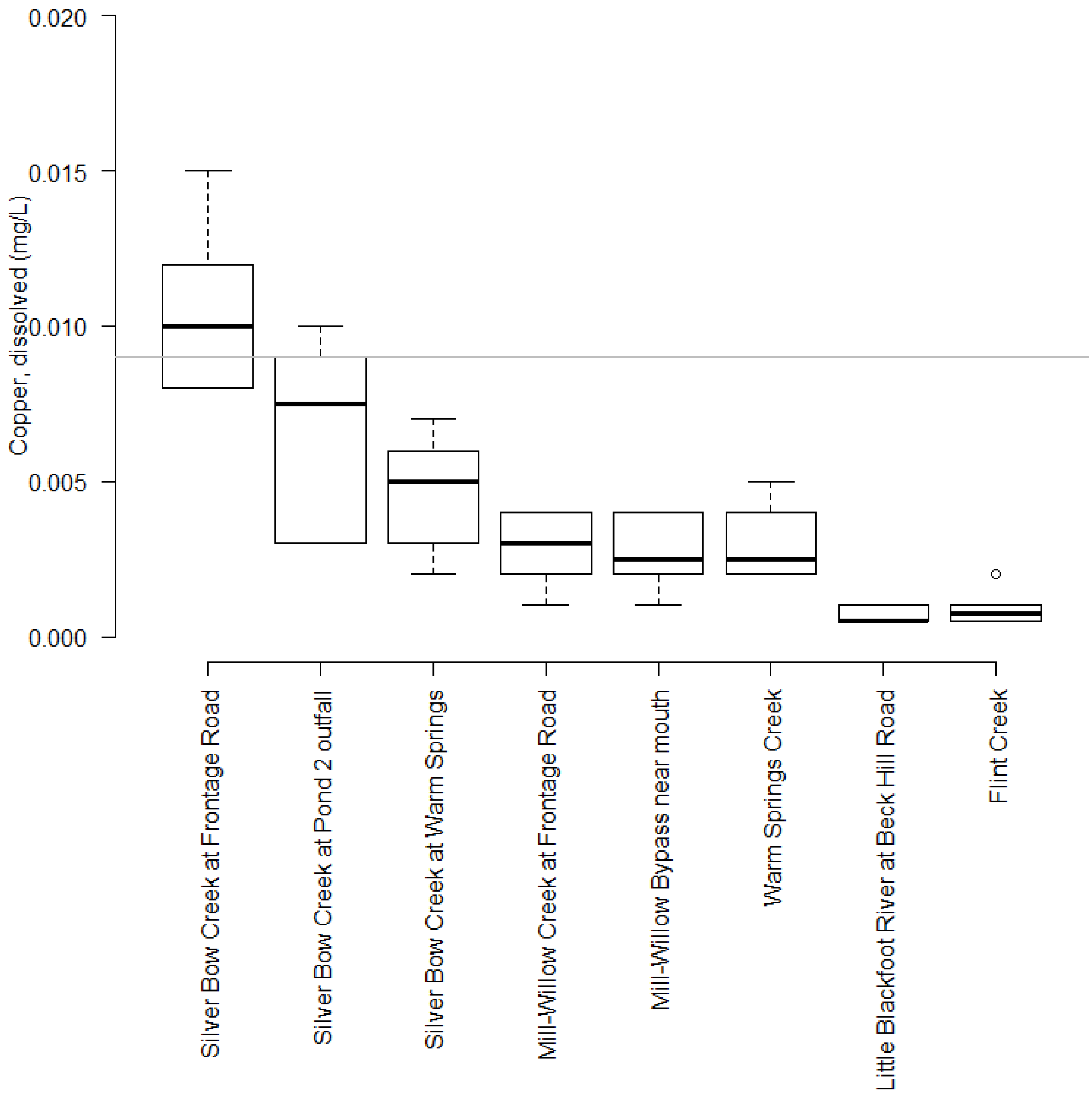

Figure 2-49. Boxplots of dissolved copper concentration at tributary sampling sites in the Clark Fork River Operable Unit, 2017. Horizontal line represents the performance goal[20] [USEPA, 2004].

[20] Assuming water hardness is 100 mg/L as CaCO3.

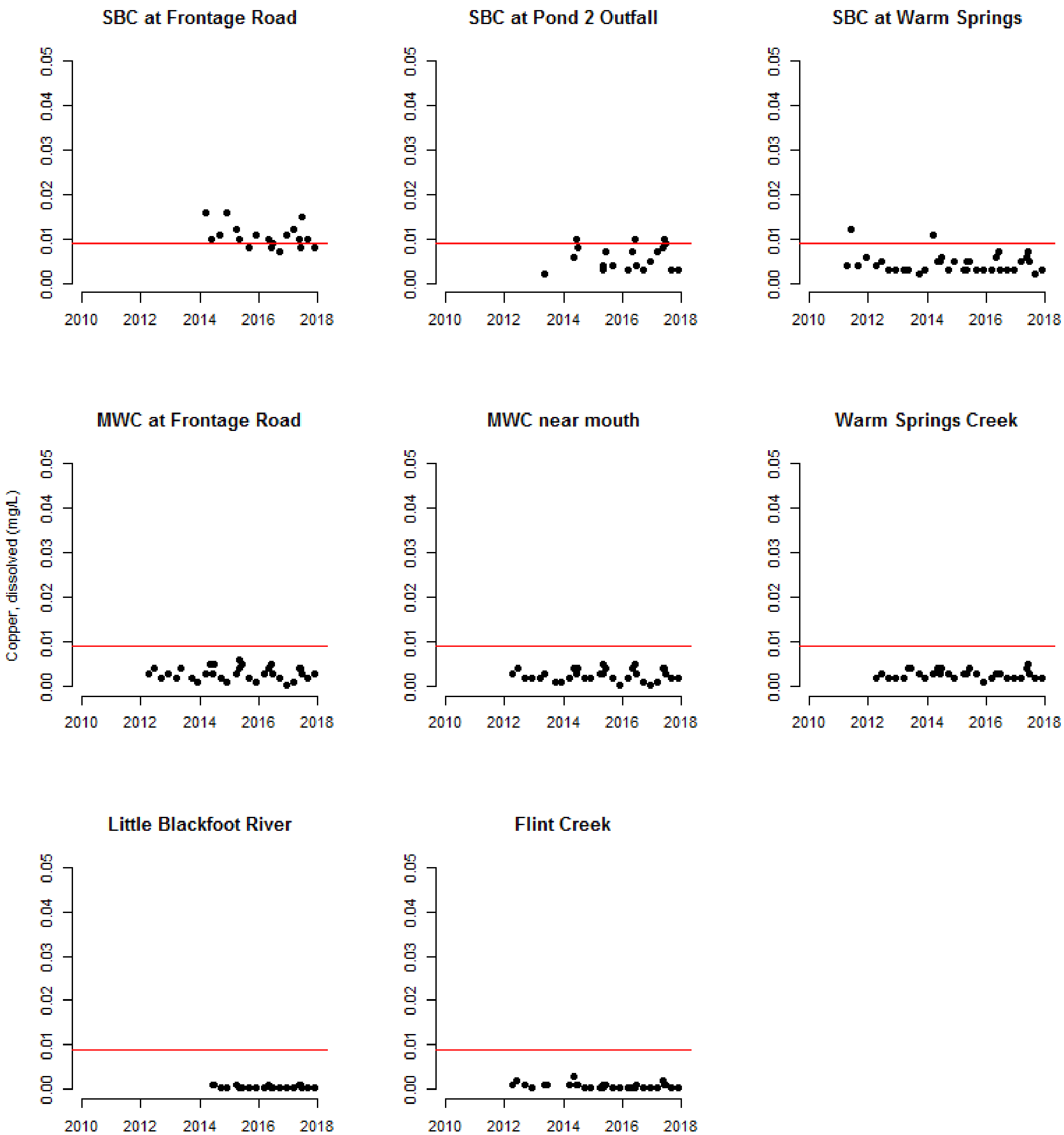

Figure 2-50. Dissolved copper concentrations at tributary sampling sites[21] in the Clark Fork River Operable Unit, 2010-2017. Horizontal lines represent the performance goal[22] [USEPA, 2004].

[21] Tributary abbreviations: SBC = Silver Bow Creek and MWC = Mill-Willow Creek.

[22] Assuming water hardness is 100 mg/L as CaCO3.

2.3.6.4 Lead

In the Clark Fork River mainstem in 2017, total recoverable lead concentrations ranged from <0.0003-0.0272 mg/L (Table 2-12). Exceedances of the lead chronic aquatic life standard occurred at all mainstem sites except near Galen (CFR-03A) at least once during Q2 sampling periods (Table 2-12).

Longitudinally, median concentrations at these mainstem sites increased through Reach A from river mile 3 (Clark Fork River near Galen; CFR-03A) to river mile 34 (Clark Fork River at Williams-Tavenner Bridge; CFR-34) and then decreased downstream to river mile 116 (Clark Fork River at Turah; CFR-116A) (Figure 2-51). Median concentrations at CFR-116A were higher than at CFR-03A (Figure 2-51).

Total recoverable lead concentrations at each Clark Fork River mainstem site were generally similar in 2017 compared to prior monitoring years, although the Q2 concentrations at Williams-Tavenner Bridge (CFR-34) were relatively high (Figure 2-52). There do not appear to be any readily discernable temporal trends in concentrations at these mainstem sites (Figure 2-52).

In the Clark Fork River tributaries in 2017, total recoverable lead concentrations ranged from <0.0003-0.0116 mg/L (Table 2-12). Exceedances of the total recoverable lead performance goal occurred in Warm Springs Creek (Q2-Peak) and in Flint Creek (all Q2 sample periods) in 2017 (Table 2-12).

Median total recoverable lead concentrations decreased, by about half, between paired sites in Silver Bow Creek above (SS-19) and below (SBC-P2) the Warm Springs Ponds (Figure 2-53). Between paired Mill-Willow Creek sites above (MCWC-MWB) and below (MWB-SBC) the Mill-Willow Bypass, median concentrations decreased slightly at the downstream site (Figure 2-53). Median concentrations in Flint Creek were substantially higher than in other tributary sites in 2017 (Figure 2-53).

Total recoverable lead concentrations at each Clark Fork River tributary site were similar in 2017 compared to prior monitoring years (Figure 2-54). There do not appear to be any readily discernable temporal trends in concentrations at these tributary sites (Figure 2-54).

Table 2-12. Total recoverable lead concentrations (mg/L) at Clark Fork River Operable Unit monitoring stations, 2017.

Site ID	Site Location	Sample Period					
		Q1	Q2			Q3	Q4
			Rising	Peak	Falling		
Mainstem Sites							
CFR-03A	Clark Fork River near Galen	0.0008	0.0017	0.0021	0.0007	ND	0.0011
CFR-07D	Clark Fork River at Galen Road	0.0014	0.0039	0.0057	0.0012	0.0003	0.0014
CFR-11F	Clark Fork River at Gemback Road	0.0014	0.0050	0.0057	0.0012	0.0003	0.0016
CFR-27H	Clark Fork River at Deer Lodge	0.0041	0.0132	0.0203	0.0033	0.0007	0.0060
CFR-34	Clark Fork River at Williams-Tavenner Bridge	0.0060	0.0139	0.0272	0.0181	0.0007	0.0035
CFR-116A	Clark Fork River at Turah	0.0022	0.0047	0.0093	0.0015	ND	0.0015
Tributary Sites							
SS-19	Silver Bow Creek at Frontage Road	0.0029	0.0023	0.0036	0.0009	0.001	0.0025
SBC-P2	Silver Bow Creek at Pond 2 Outfall	0.0011	0.0008	0.0008	ND	ND	0.0017
SS-25	Silver Bow Creek at Warm Springs	0.0013	0.0012	0.0014	0.0006	0.0003	0.0013
MCWC-MWB	Mill-Willow Creek at Frontage Road	0.0023	0.0017	0.0019	0.0012	0.0014	0.0030
MWB-SBC	Mill-Willow Bypass near mouth	0.0016	0.0019	0.0016	0.0008	0.0003	0.0006
WSC-SBC	Warm Springs Creek near mouth	0.0007	0.0007	0.0025	0.0007	0.0004	0.0022
LBR-CFR-02	Little Blackfoot River at Beck Hill Road	ND	0.0008	0.0005	ND	ND	0.0011
FC-CFR	Flint Creek near mouth	0.0046	0.0071	0.0116	0.0058	0.0086	0.0023

--- Not sampled.

ND Not detected at analytical reporting limit.

(yellow) Exceeds chronic aquatic life standard [DEQ, 2017].

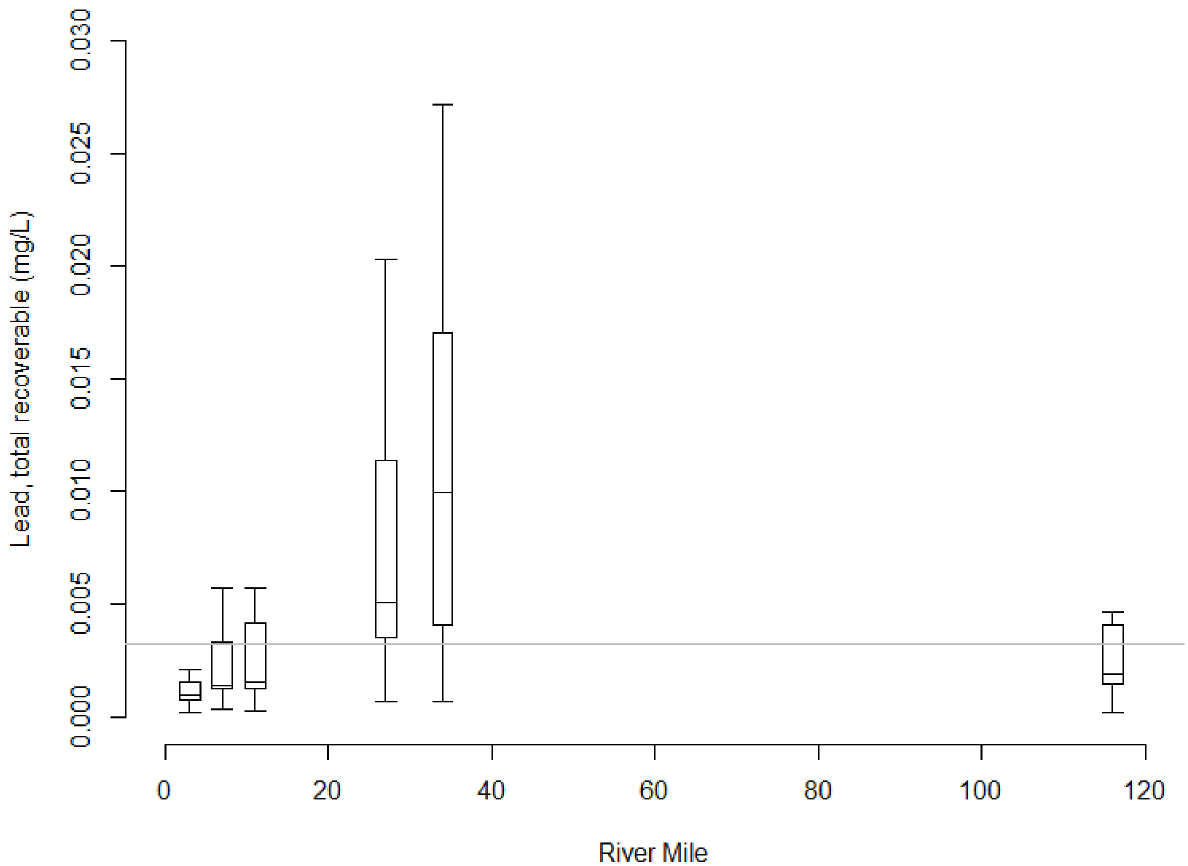

Figure 2-51. Boxplots of total recoverable lead concentration by river mile at mainstem sampling sites in the Clark Fork River Operable Unit, 2017. Horizontal line represents the performance goal[23] [USEPA, 2004].

[23] Assuming water hardness is 100 mg/L as CaCO3.

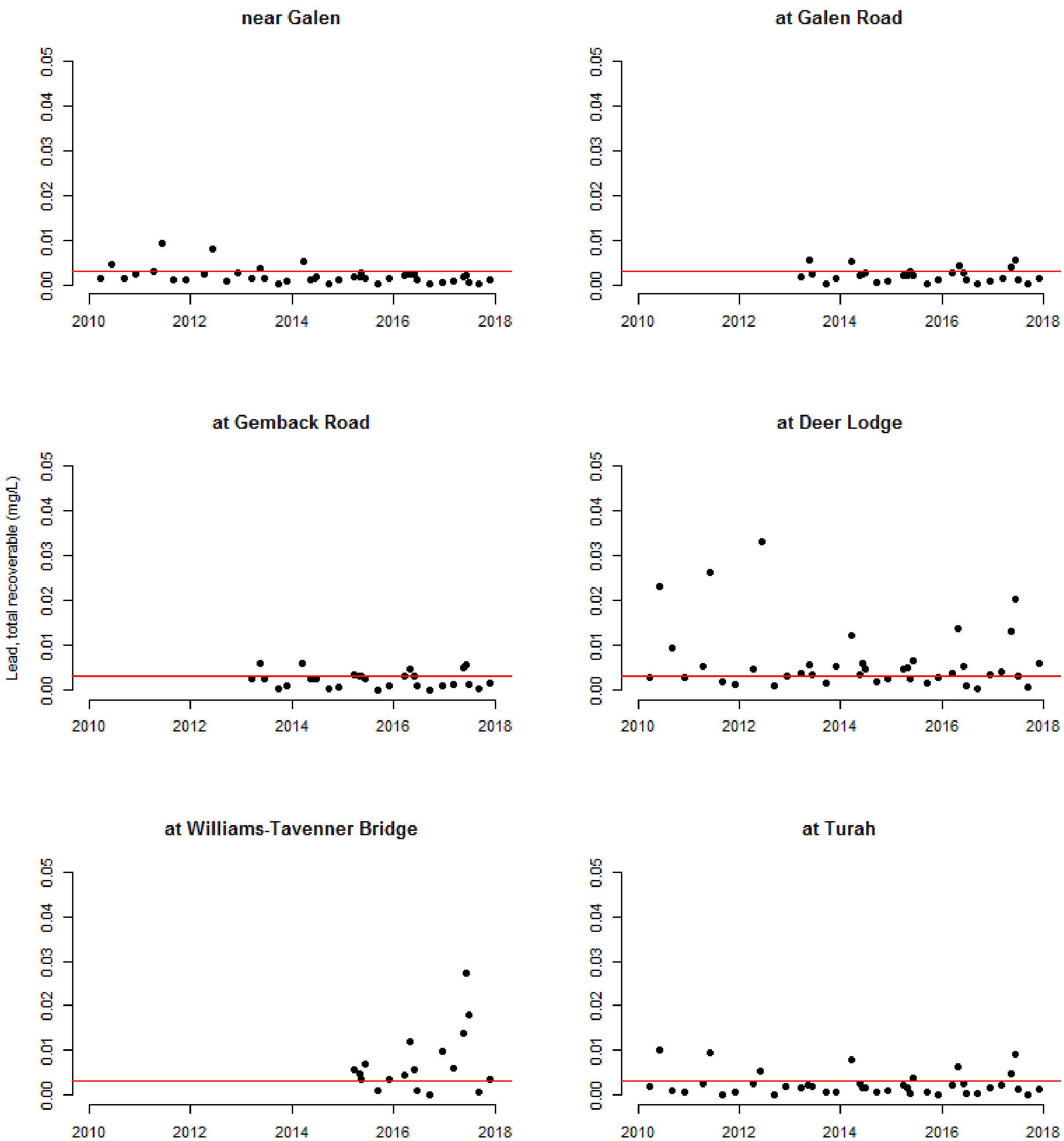

Figure 2-52. Total recoverable lead concentrations at mainstem sampling sites in the Clark Fork River Operable Unit, 2010-2017. Horizontal lines represent the performance goal[24] [USEPA, 2004].

[24] Assuming water hardness is 100 mg/L as CaCO3.

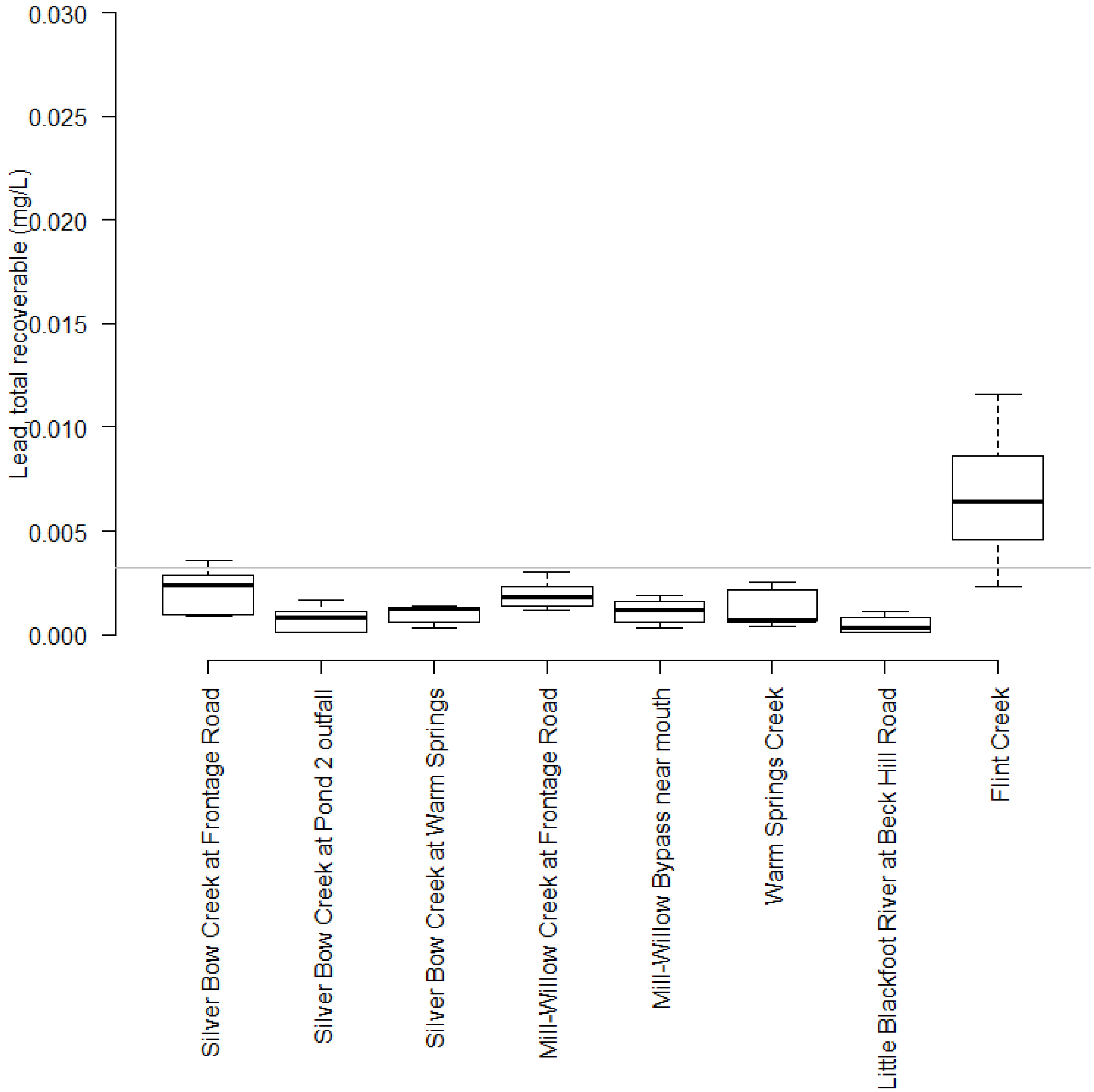

Figure 2-53. Boxplots of total recoverable lead concentration at tributary sampling sites in the Clark Fork River Operable Unit, 2017. Horizontal line represents the performance goal[25] [USEPA, 2004].

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[25] Assuming water hardness is 100 mg/L as CaCO3.

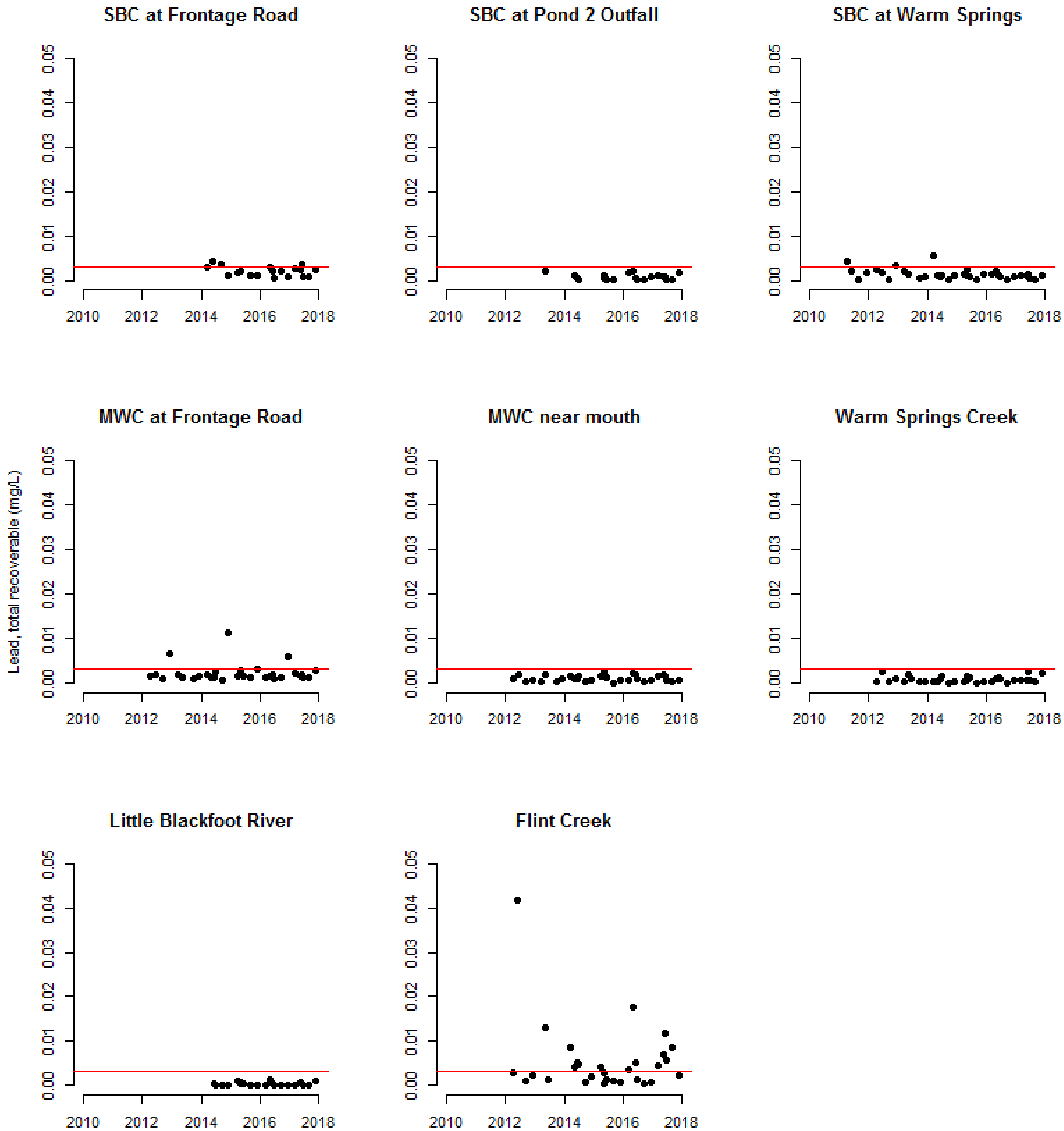

Figure 2-54. Total recoverable lead concentrations at tributary sampling sites[26] in the Clark Fork River Operable Unit, 2010-2017. Horizontal lines represent the performance goal[27] [USEPA, 2004].

[26] Tributary abbreviations: SBC = Silver Bow Creek and MWC = Mill-Willow Creek.

[27] Assuming water hardness is 100 mg/L as CaCO3.

2.3.6.5 Zinc

In the Clark Fork River mainstem in 2017, total recoverable zinc concentrations ranged from <0.008-0.147 mg/L (Table 2-13). One exceedance of the aquatic life standard occurred in the mainstem sites: at the Williams-Tavenner Bridge (CFR-34) (Table 2-13).

Longitudinally, median zinc concentrations at these mainstem sites increased gradually through Reach A from river mile 3 (Clark Fork River near Galen; CFR-03A) to river mile 34 (Clark Fork River at Williams-Tavenner Bridge; CFR-34) and then decreased downstream to river mile 116 (Clark Fork River at Turah; CFR-116A) (Figure 2-55).

Total recoverable zinc concentrations at each Clark Fork River mainstem site were generally similar in 2017 compared to prior monitoring years (Figure 2-56). Over the period of monitoring at these mainstem sites, there do not appear to be any temporal trends in total recoverable zinc concentrations given the variability in these data (Figure 2-56).

In the Clark Fork River tributaries in 2017, total recoverable zinc concentrations ranged from <0.008-0.126 mg/L (Table 2-13). No exceedances of the total recoverable zinc performance goal occurred in the Clark Fork River tributaries in 2017 (Table 2-13).

Median total recoverable zinc concentrations decreased, by more than half, between paired sites in Silver Bow Creek above (SS-19) and below (SBC-P2) the Warm Springs Ponds (Figure 2-57). Between paired Mill-Willow Creek sites above (MCWC-MWB) and below (MWB-SBC) the Mill-Willow Bypass, median concentrations were similar (Figure 2-57). Median concentrations in Flint Creek were slightly higher in all other tributary sites except SS-19 (Figure 2-57).

Total recoverable zinc concentrations at each Clark Fork River tributary site were similar in 2017 compared to prior monitoring years (Figure 2-58). No sites appear to have increasing or decreasing trends in concentrations (Figure 2-58).

Table 2-13. Total recoverable zinc concentrations (mg/L) at Clark Fork River Operable Unit monitoring stations, 2017.

Site ID	Site Location	Sample Period					
		Q1	Q2			Q3	Q4
			Rising	Peak	Falling		
Mainstem Sites							
CFR-03A	Clark Fork River near Galen	0.014	0.015	0.018	ND	ND	0.010
CFR-07D	Clark Fork River at Galen Road	0.015	0.026	0.037	0.012	ND	0.012
CFR-11F	Clark Fork River at Gemback Road	0.018	0.035	0.040	0.010	ND	0.015
CFR-27H	Clark Fork River at Deer Lodge	0.033	0.080	0.118	0.025	0.016	0.030
CFR-34	Clark Fork River at Williams-Tavenner Bridge	0.046	0.085	0.147	0.035	0.010	0.027
CFR-116A	Clark Fork River at Turah	0.020	0.036	0.059	0.016	ND	0.016
Tributary Sites							
SS-19	Silver Bow Creek at Frontage Road	0.119	0.055	0.058	0.034	0.043	0.126
SBC-P2	Silver Bow Creek at Pond 2 Outfall	0.020	0.014	0.018	ND	ND	0.018
SS-25	Silver Bow Creek at Warm Springs	0.018	0.013	0.014	ND	ND	0.012
MCWC-MWB	Mill-Willow Creek at Frontage Road	0.012	0.008	0.008	ND	ND	0.016
MWB-SBC	Mill-Willow Bypass near mouth	0.011	0.009	ND	ND	ND	ND
WSC-SBC	Warm Springs Creek near mouth	ND	ND	0.016	0.009	ND	0.011
LBR-CFR-02	Little Blackfoot River at Beck Hill Road	ND	ND	ND	ND	ND	ND
FC-CFR	Flint Creek near mouth	0.015	0.023	0.032	0.019	0.013	0.008

ND Not detected at analytical reporting limit.

Exceeds chronic/acute aquatic life standard [DEQ, 2017].

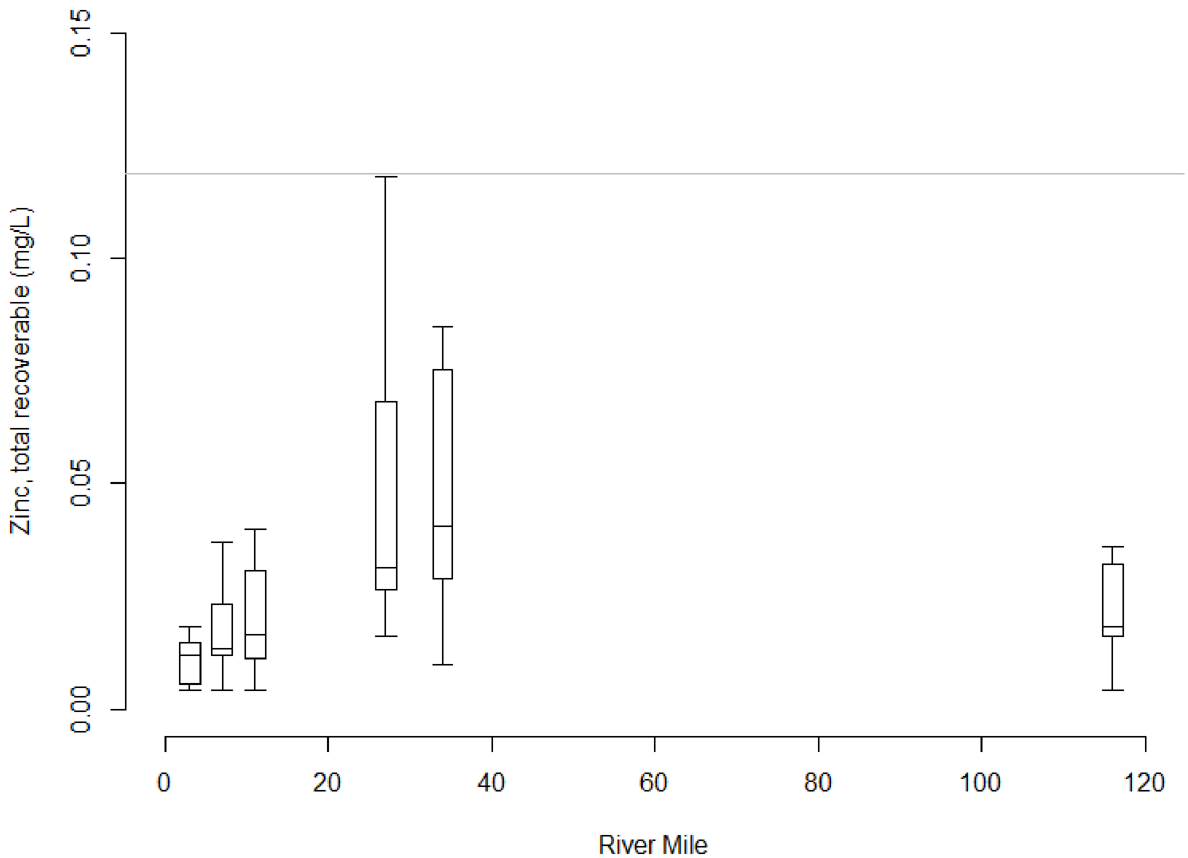

Figure 2-55. Boxplots of total recoverable zinc concentration by river mile at mainstem sampling sites in the Clark Fork River Operable Unit, 2017. Horizontal line represents the performance goal[28] [USEPA, 2004].

[28] Assuming water hardness is 100 mg/L as CaCO3.

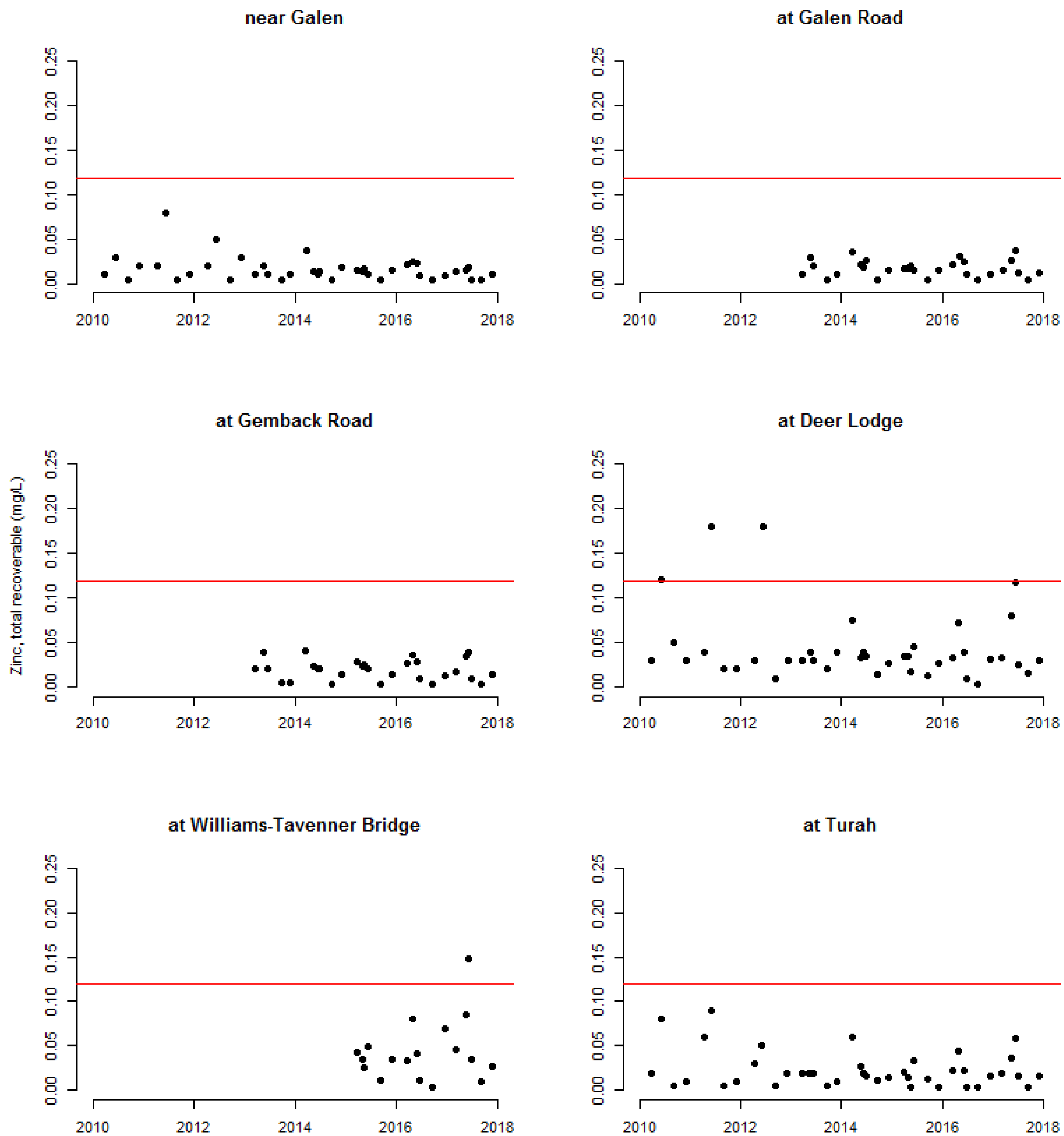

Figure 2-56. Total recoverable zinc concentrations at mainstem sampling sites in the Clark Fork River Operable Unit, 2010-2017. Horizontal lines represent the performance goal[29] [USEPA, 2004].

[29] Assuming water hardness is 100 mg/L as CaCO3.

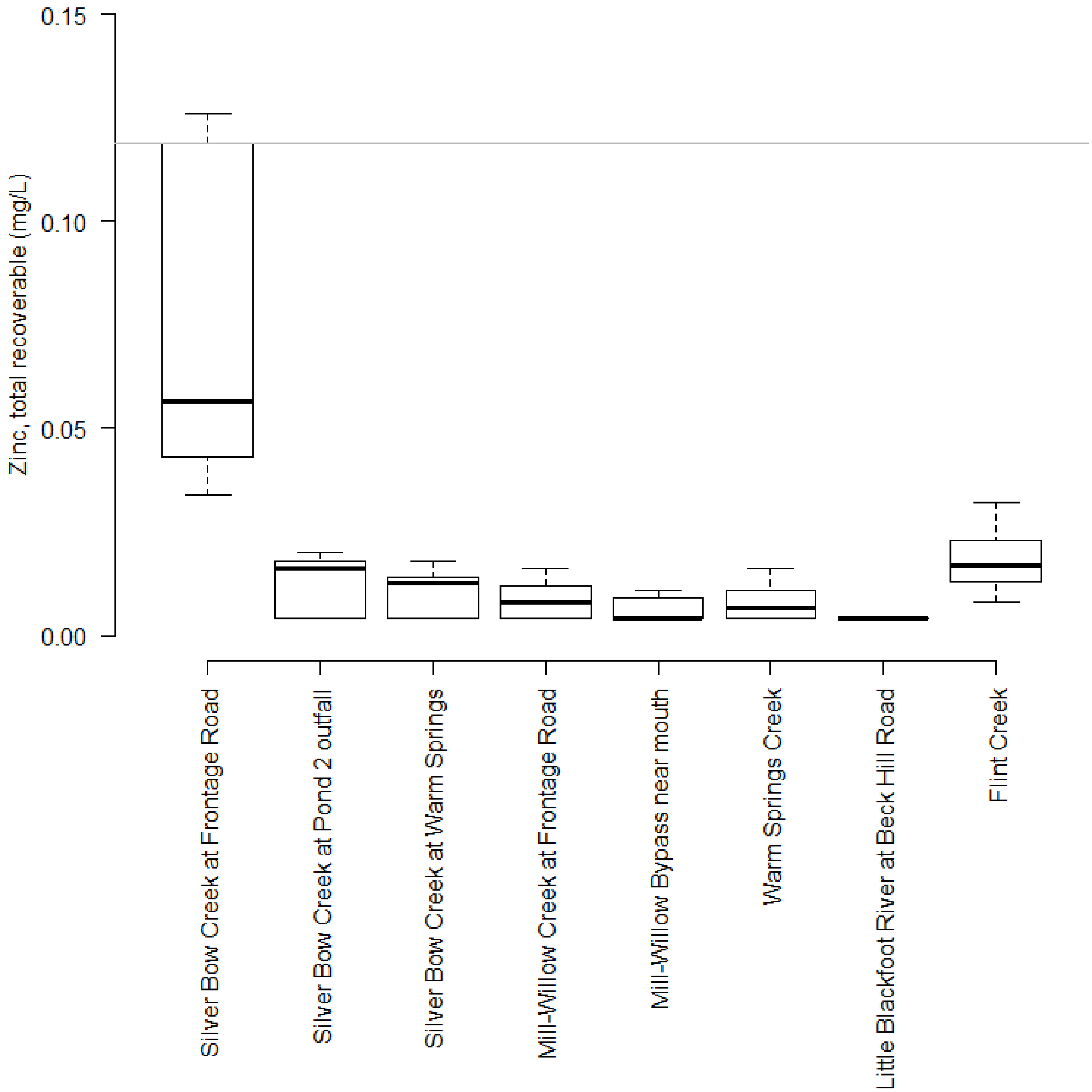

Figure 2-57. Boxplots of total recoverable zinc concentration at tributary sampling sites in the Clark Fork River Operable Unit, 2017. Horizontal line represents the performance goal[30] [USEPA, 2004].

[30] Assuming water hardness is 100 mg/L as $CaCO3$.

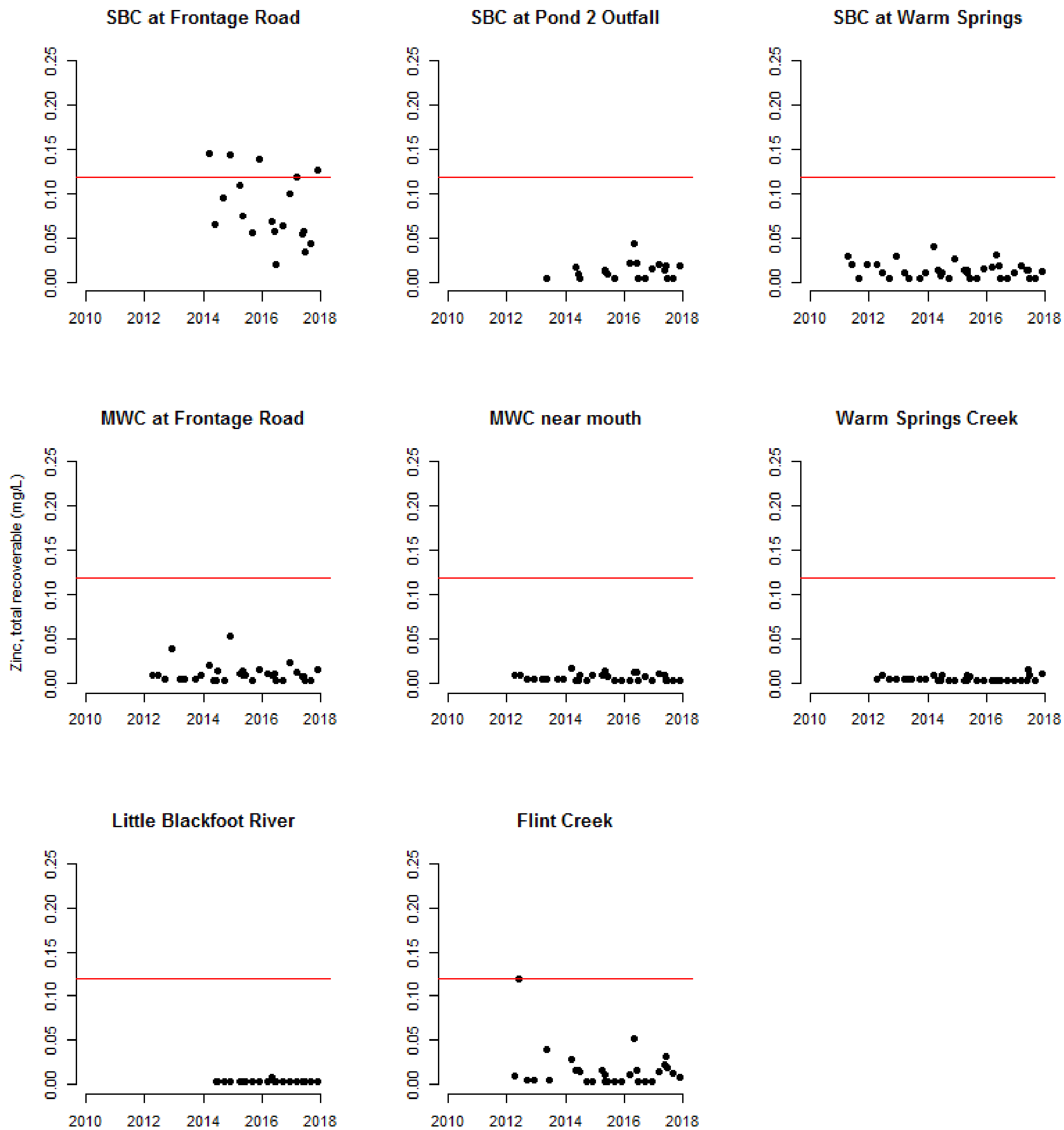

Figure 2-58. Total recoverable zinc concentrations at tributary sampling sites[31] in the Clark Fork River Operable Unit, 2010-2017. Horizontal lines represent the performance goal[32] [USEPA, 2004].

[31] Tributary abbreviations: SBC = Silver Bow Creek and MWC = Mill-Willow Creek.

[32] Assuming water hardness is 100 mg/L as CaCO3.

2.3.7 Other Metals

2.3.7.1 Mercury

In the Clark Fork River near Drummond (CFR-84F) in 2017, total mercury concentrations ranged from 0.000012-0.000182 mg/L (Table 2-14). All Q2 samples exceeded the mercury human health surface water standard (Table 2-14). In Flint Creek (FC-CFR) in 2017, total mercury concentrations ranged from 0.000035-0.000438 mg/L (Table 2-14). Exceedances of the mercury human health surface water standard occurred in all sample periods except Q3 (Table 2-14).

Table 2-14. Total mercury concentrations (mg/L) at Clark Fork River Operable Unit monitoring stations, 2017.

Site ID	Site Location	Sample Period					
		Q1	Q2			Q3	Q4
			Rising	Peak	Falling		
Mainstem Sites							
CFR-84F	Clark Fork River near Drummond	0.000047	0.000151	0.000182	0.000071	0.000012	0.000024
Tributary Sites							
FC-CFR	Flint Creek near mouth	0.000180	0.000269	0.000438	0.000360	0.000035	0.000114

Exceeds human health surface water standard (0.000050 mg/L; DEQ, 2017).

2.3.7.2 Methylmercury

In the Clark Fork River near Drummond in 2017, methylmercury concentrations ranged from 0.166-1.19 ng/L (Table 2-15). In Flint Creek in 2017, methylmercury concentrations ranged from 0.887-1.49 ng/L (Table 2-15).

Table 2-15. Methylmercury concentrations (ng/L) at Clark Fork River Operable Unit monitoring stations, 2017.

Site ID	Site Location	Sample Period					
		Q1	Q2			Q3	Q4
			Rising	Peak	Falling		
Mainstem Sites							
CFR-84F	Clark Fork River near Drummond	0.644	0.717	1.19	0.425	0.166	0.431
Tributary Sites							
FC-CFR	Flint Creek near mouth	1.27	1.49	1.48	0.887	1.03	0.800

2.3.8 Data Validation

Data derived from laboratory analysis of surface water samples collected at upper Clark Fork River locations were validated through field quality control samples (i.e., field duplicates and field blanks) and laboratory control samples (lab duplicates, blanks, spikes, and reference and calibration standards. Analysis of field quality measures are described in Appendix A. Results of laboratory quality control measures are described in Appendix B. Data quality objectives (DQOs) were evaluated for accuracy and precision. These DQOs were largely met in 2017 with a few exceptions.

Analyte concentrations were measured in field blanks to evaluate sampling accuracy and the extent to which the field techniques may have contaminated the samples. Twelve field blank samples were collected in 2017 and twenty-three analyte concentrations were measured in each. Two additional analyte concentrations (mercury and methylmercury) were measured in six field blanks. Therefore, in total 288 analyte concentrations were evaluated in the field blanks and 3.8 percent (11 of 288) of the analytes had concentrations equal to or greater than the respective analytical reporting limit. All but one of the analytes with a detectable concentration in the field blanks was dissolved zinc (detected in 83 percent or 10 of 12 field blanks). In the ten dissolved field blank samples with zinc concentrations above the reporting limit, concentrations ranged from 0.008-0.013 mg/L (mean = 0.011 mg/L). Total suspended sediment was detected in one (8 percent) field blank at a concentration of 3 mg/L (reporting limit [RL] = 1 mg/L).

Analyte concentrations were compared in field sample and field duplicate pairs to evaluate overall sampling precision. Twelve field sample and field duplicate pairs were collected in 2017 and twenty-three analytes were analyzed in each. Six field sample and field duplicate pairs were also analyzed for total mercury and methylmercury concentrations. Therefore, in total 288 comparisons were made between field sample and field duplicate pairs in 2017. The relative percent difference (RPD) of each of those pairs exceeded 25 percent in 1.7 percent (5 of 288) of the pairs. Some pairs had RPD ≥25 percent but either the field sample, field duplicate, or both had a concentration that was less than five times greater than the RL and therefore the RPD from those pairs were disregarded. Field sample and field duplicate pairs with RPD ≥25 percent, and sample and duplicate concentrations ≥5 times the RL included: methylmercury at FC-CFR on June 7 and June 27, 2017 (RPD = 34 percent and 42 percent, respectively); total recoverable cadmium at FC-CFR on September 5, 2017 (RPD = 50 percent); total recoverable copper FC-CFR on September 5, 2017 (RPD = 40 percent); and total recoverable lead at FC-CFR on September 5, 2017 (RPD = 42 percent).

2.4 DISCUSSION

2.4.1 Streamflows

Compared to long-term median streamflows at the upper Clark Fork River sites, streamflows in 2017 were generally characterized by normal to slightly higher than normal streamflows. Despite strong mountain snowpack in 2017 which supported the strong runoff streamflows at most sites, some sites still had severe, and in some sites, prolonged low streamflows during the summer. For example, streamflows throughout the month of August in the Clark Fork River near Drummond were approximately 50-100 ft/s^3 below normal. Summer streamflows at Deer Lodge were 20-30 percent lower than normal and the duration of those low streamflows extended well into September which is far longer than normal. The annual minima at Flint Creek reached 7 ft/s3, or approximately one third of the long-term median.

2.4.2 Field Parameters

2.4.2.1 Water Temperature

Water temperature has considerable chemical and biological significance in riverine systems. Stream temperatures reflect seasonal changes in net solar radiation as well as daily changes in air temperature, and vary as a function of stream morphological characteristics, groundwater inputs, shading, the presence of particulate matter in the water column, and other factors. Optimal water temperature for most trout species is approximately 12–14 C. Sustained temperatures in the 20–25 °C range may be fatal for trout.

Temperature monitoring results for the upper Clark Fork River monitoring stations during 2017 indicated modest seasonal and spatial variations that periodically were higher than the preferred range for cold water organisms such as trout. The maximum recorded water temperatures in the mainstem reached 18.1 °C (at Deer Lodge) and 20.5 °C in the tributaries (Silver Bow Creek).

However, stream temperatures are extremely variable because of weather and diel variation and this monitoring program is not intended to characterize extreme temperature variations at each site. More detailed hourly temperature data, collected by Montana Fish, Wildlife and Parks, has indicated that water temperatures in the Clark Fork River and tributaries are at times extremely stressful for trout often exceeding 20 °C and occasionally exceeding 25 °C at many of these sites.

2.4.2.2 pH

Water pH measures the acidity of water as the concentration of hydrogen ions on a logarithmic scale. Acidity is influenced by water temperature, although the relationship is not linear, and typically shows a weak inverse relationship to streamflow as concentrations of base minerals tend to become diluted during runoff conditions. Acidity typically fluctuates on a diel cycle in relation to stream metabolism, with pH highest during the day. As dissolved carbon dioxide (a weak acid) levels increase during the night (because photosynthesis does not occur), pH levels decrease. Stream pH has direct and indirect effects on water chemistry and the biota of aquatic systems. If pH falls below 6.5, salmonid egg production, salmonid hatching success, and emergence success of some aquatic insects may be reduced. The solubility of some metals varies with pH. This is important in systems such as the Clark Fork River where metal concentrations in sediments are elevated. Stream pH also affects a variety of other instream chemical equilibria, for example the proportion of ammonia present in the toxic (un-ionized) form.

DEQ stream classifications in the upper Clark Fork River watershed vary by stream and recommended pH levels differ based on the classification. In the Clark Fork River mainstem downstream from Deer Lodge recommended pH is a range of 6.5-8.5 and upstream from Deer Lodge the recommended range is 6.5-9.0 [ARM 17.30.607]. Three mainstem sites had pH exceeding the recommended range: near Galen (Q1 and Q2-Rising), at Galen Road (Q2-Rising), and at Gemback Road (Q2-Falling and Q3) during three sample periods of 2017. Based on those exceedances, DEQ could potentially enact restrictions for any discharges to the river which were above 8.5. Causes of the elevated pH at this site may have been related to increased primary productivity from nutrient enrichment.

In addition, one tributary site (Silver Bow Creek at the Pond 2 outfall; SBC-P2) had pH above the recommended range (Silver Bow Creek is classified as "I"; recommended pH range is 6.5-9.5; ARM 17.30.607). On September 6, 2017 pH at SBC-P2 was 9.81. In the outfall of the Warm Springs Ponds, pH in Silver Bow Creek exceeded 9.0 during 3 of 6 (50 percent) 2017 sample periods. Elevated daytime pH may be the result of excessive liming, diel cycles related to high productivity from nutrient enrichment, or both [Nimmick et al., 2011; Chatham, 2012].

2.4.2.3 Conductivity

Conductivity is a quantitative measure of the ability of an aqueous solution to convey an electrical current and is a function of water temperature and of the concentration of dissolved ions in water. Conductivity provides an approximation of the concentration of dissolved solids in water as well as its potential suitability for uses that may be limited by excessive salinity. Conductivity also gives general insight into spatial and seasonal changes in water chemistry.

Elevated levels of conductivity reflecting high dissolved solids may limit some water uses, such as irrigation or drinking water. Very low conductivity, as affected by watershed geology, may contribute to low productivity of associated biological systems. Conductivity tends to be inversely proportional to streamflow due to dilution from spring snowmelt runoff, and we observed that conductivity was generally highest during the late summer sample period when streamflows were lowest. Conductivity measured in the Clark Fork River mainstem in 2017 ranged from 148-573 μS/cm. In comparison, the USEPA states, "Studies of inland fresh waters indicate that streams supporting good mixed fisheries have a (conductivity) range between 150 and 500 µS/cm" [USEPA, 2015].

2.4.2.4 Dissolved Oxygen

Dissolved oxygen refers to the amount of oxygen dissolved in water. The capacity of water to hold oxygen in solution is inversely proportional to water temperature. In addition to water temperature, instream dissolved oxygen concentrations are affected by respiration of organisms, photosynthesis of aquatic plants, the biochemical oxygen demand of substances in the water, and the solubility of atmospheric oxygen. Dissolved oxygen levels fluctuate seasonally and over diel cycles due to variation in rates of stream metabolism.

Adequate dissolved oxygen concentrations are required by biological stream communities and for the decomposition of organic matter in the stream. Acceptable levels of dissolved oxygen for the protection of aquatic life are defined in the Montana water quality standards [DEQ, 2017].

No dissolved oxygen concentrations in the CFROU in 2017 indicated water quality or water use limitations associated with low oxygen concentrations (range: 8.3-14.0 mg/L). However, the lowest dissolved oxygen concentrations are expected to occur in the pre-dawn hours and monitoring occurred in the daytime at all sites.

Recent work indicates that anoxic conditions along the stream bottom of the Clark Fork River beneath *Cladophora* mats in Reach C [M. Vallett, University of Montana, *unpublished data*]. It is not known if those conditions also occur in other portions of the Clark Fork River but *Cladophora* growth is prolific in Reach A and B of the CFROU as well. These anoxic conditions may have a strong influence on stream ecology in the Clark Fork River.

2.4.2.5 Turbidity

Turbidity refers to the amount of light that is absorbed or scattered by water. Increasing turbidity or "cloudiness" in surface waters usually results from the presence of suspended silt or clay particles, organic matter, colored organic compounds, or microorganisms. Turbidity usually, but not always, correlates closely with the total suspended sediment concentration which measures the weight of suspended matter in solution. The lack of correlation between those parameters may be due to variation in particle sizes, weights, or refractive properties of the substances that contribute to turbidity.

Turbidity is an important parameter for drinking water. Elevated turbidity may impede recreational and aesthetic uses of water. High turbidity may adversely affect feeding, growth, and habitat quality for salmonids and other fishes, and may influence surface water temperatures. The DEQ has established maximum allowable increases above naturally occurring turbidity. The allowable increase is 10 nephelometric turbidity units (NTU) for C-2 class streams (Clark Fork River from Warm Springs Creek to Cottonwood Creek), and five units for C-1 (Clark Fork River from Cottonwood Creek to the Little Blackfoot River) and B-1 (remainder of Clark Fork) class streams [ARM 17.30.623; ARM 17.30.626–627].

Turbidity during the 2017 monitoring events was generally low (10 NTU or less), although during the Q2-Rising and Q2-Peak sample periods turbidity was relatively high at some sites. For example, turbidity was between 18 NTU and 28 NTU at sites from Deer Lodge to Turah during the Q2-Rising event and between 26 NTU and 41 NTU at the same sites during the Q2-Peak event. Although turbidity was high, no consecutive sites sampled on the same day had a turbidity increase of 10 NTU in 2017.

2.4.3 Total Suspended Sediment

Total suspended sediment measures the mass of material suspended in a given volume of water. Suspended sediment measures sediment in the water column as opposed to sediment transported along the stream bottom, which is known as bedload. Suspended sediment in streams generally includes a range of particle sizes which may vary with watershed geology, stream velocity, bed form, and turbulence. Excess fine sediment interferes with most water uses and may have particularly adverse effects on benthic invertebrate and salmonid fish growth and reproduction. Increased suspended sediment reduces light penetration and may affect primary production by aquatic plants and the morphology of alluvial stream channels. In the Clark Fork River system, many COC concentrations are directly correlated with suspended sediment concentrations.

In general, total suspended sediment concentrations had spatial and seasonal patterns very similar to those for turbidity. The highest mainstem suspended sediment concentrations occurred in the lower half of Reach A at Deer Lodge and at Williams-Tavenner Bridge.

2.4.4 Common Ions

Common ions describe basic water chemistry. Certain ions, such as sulfate, may indicate the presence of mine related contaminants. Calcium and magnesium ions contribute to water hardness, which helps to buffer the toxic effects of some metals. Aquatic life toxicity criteria for metal COCs vary directly in relation to hardness. Hardness mitigates metals toxicity by impeding the rate at which aquatic organisms absorb metals through the gills. Carbonate and bicarbonate alkalinity contribute to the buffering system of surface waters to resist changes in pH. Levels of water hardness and alkalinity also strongly influence the productivity of aquatic systems. Western freshwater fisheries typically have alkalinity of 100–200 mg/L. In 2017, the Clark Fork mainstem alkalinity ranged from 58-180 mg/L. Based on previous monitoring, calcium is the dominant cation at the upper Clark Fork River monitoring network stations.

Water hardness in the Clark Fork River mainstem stations in 2017 ranged from “moderately hard” to “very hard”. In comparison, most rivers in western Montana have “moderately hard” to “hard” water [USGS, 2015]. The moderately elevated water hardness in the Clark Fork River relative to other regional rivers is likely beneficial overall for aquatic life because water hardness mitigates toxicity of heavy metals [USEPA, 1986]. Alkalinity in the upper mainstem Clark Fork River was moderate to high which reflects a well buffered system, with good potential for fish production barring other limitations.

In Mill-Willow Creek sulfate concentrations increased on average by about five times from above to below the Mill-Willow Bypass section of Mill-Willow Creek (between sites MCWC-MWB and MWB-SBC). These results suggest that there are sources of sulfate in the floodplain along the Mill-Willow Bypass stream corridor.

2.4.5 Nutrients

Numeric water quality standards have been adopted for nutrients in the Clark Fork River from the Warm Springs Creek confluence to the Blackfoot River confluence, a river section which encompasses most of the CFROU [ARM 17.30.631]. The standards apply only to the summer season (June 21 through September 21). The standards for this segment of the Clark Fork River are 0.300 mg/L for total nitrogen and 0.020 mg/L for total phosphorus [ARM 17.30.631]. The standards do not apply to sample sites located on tributaries to the Clark Fork River. Instead, summertime base numeric nutrient standards for the Middle Rockies Ecoregion apply to the tributaries during the July 1 to September 30 period. These standards are 0.300 mg/L for total nitrogen and 0.030 mg/L for total phosphorus [DEQ, 2014].

The highest total nitrogen concentrations in the Clark Fork River mainstem in 2017 were at Deer Lodge or at the Williams-Tavenner Bridge. Two mainstem sites exceeded the relevant total nitrogen standard in 2017, which was only applicable during the Q2-Falling and Q3 events. Exceedances of the total nitrogen standard were 0.40 mg/L at Deer Lodge (CFR-27H) in Q3 and 0.32 mg/L at Williams-Tavenner Bridge (CFR-34) in Q3. About half the total nitrogen concentrations at CFR-27H and CFR-34 in Q3 was inorganic nitrogen (nitrate plus nitrite) which is bioavailable.

Nutrient levels in Silver Bow Creek at Frontage Road, upstream from the Warm Springs Ponds, exceeded the total nitrogen standard by more than three times in Q3. In Q1 at the same site, total nitrogen levels were approximately three times higher than at any site in the CFROU monitoring network, and essentially 90 percent of the nitrogen was bioavailable (i.e., primarily nitrate plus nitrite).

All mainstem sites (near Galen and at Williams-Tavenner Bridge) had total phosphorus concentrations exceeding the Clark Fork River mainstem-specific total phosphorus standard during the Q2-Falling event but only one site (at Williams-Tavenner Bridge) had a concentration exceeding that standard. It is unknown if this phosphorus in the Clark Fork River is primarily derived from natural (i.e., geologic) characteristics in the watershed or from nutrient enrichment from anthropogenic influences. In the tributaries, all Silver Bow Creek sites and the Flint Creek site exceeded the total phosphorus standard in Q3.

2.4.6 Contaminants of Concern

Overall, Reach A, extending from the Warm Springs Creek confluence to the Little Blackfoot River confluence, has the largest volume of streamside tailings in the CFROU. The upper-most portion of the river located upstream from the town of Deer Lodge has been identified as an area of relatively heavy COC loading to the Clark Fork River [Sando et al., 2014]. Surface water monitoring data collected in 2017 represents the eighth year of monitoring in the CFROU for this monitoring program.

Monitoring from 2010-2012 represented baseline conditions in the CFROU immediately prior to the start of remediation. Because remedial activities were just beginning in 2013, it was unlikely that monitoring in during that year would demonstrate much change in COC levels in the river from pre-remediation concentrations in 2010-2012. The 2014 monitoring year was the first year following complete cleanup of the Phase 1 project area. In 2015, remedial actions were in progress in additional river sections (Phases 2, 5, and 6) stretching approximately 6.4 miles in total and those cleanup actions were completed by the end of 2017. Remedial actions in other portions of Reach A are likely to occur over a ten-year period.

In 2017 exceedances of performance goals occurred for all COCs but, in the mainstem, were most frequent for arsenic. Of 36 samples collected in the Clark Fork River mainstem in 2017 (from six sites during six sample periods), performance goal exceedances occurred for zinc in one sample (3 percent), for cadmium and copper in two samples (6 percent), for lead in ten samples (28 percent), and for arsenic in 20 samples (56 percent).

Arsenic exceedances of the performance goals were most consistent in Reach A (all mainstem sites except at Turah) during Q2 and Q3. All samples from Reach A in Q2 and Q3 exceeded the performance goal for arsenic. The arsenic performance goal has specific requirements for dissolved concentrations (0.010 mg/L) and total recoverable concentrations (0.018 mg/L). Exceedance of the dissolved arsenic performance goal was more common than exceedance of the total recoverable arsenic performance goal. Silver Bow Creek below the Warm Springs Ponds and Mill-Willow Creek were clearly sources of arsenic to the Clark Fork River as 75 percent (18 of 24) of the samples from sites in those stream sections exceeded the dissolved arsenic performance goal and 54 percent (13 of 24) of the samples exceeded the total recoverable performance goal.

Arsenic concentrations in Silver Bow Creek entering the Warm Springs Ponds (at Frontage Road) were always considerably lower than the concentrations leaving the ponds (at Warm Springs) indicating that arsenic is likely remobilized in the ponds as described by others [Chatham, 2012]. These results also support findings of the USGS monitoring program which identified the Warm Springs Ponds, the Mill-Willow Bypass, and groundwater near the Warm Springs Ponds as substantial arsenic sources to the upper Clark Fork River [Sando et al., 2014].

We did not conduct any formal statistical analysis on these data because we believe those analyses are premature currently in the CFROU. Instead, this report describes our own observations about the data from the plots presented. In the Clark Fork mainstem, it appears that the variability in the data would likely swamp any ability to discern changes in average COC concentrations through time given the relatively short period of monitoring to date and the variability in the data.

2.4.7 Other Metals

Monitoring data continues to implicate Flint Creek as a primary source of mercury and methylmercury to the Clark Fork River.

2.4.8 Data Validation

Generally, this monitoring program has satisfied the data quality objectives and data quality indicators specified in the QAPP [Atkins, 2013]. However, quality control procedures have consistently demonstrated that trace level contamination of dissolved field samples with zinc occurs. The zinc contamination is isolated in the dissolved samples (strongly suggesting that the filtering apparatus is responsible). Dissolved zinc concentrations are not used for evaluation of performance goals. Generally, zinc contamination levels were low and data quality objectives and data quality indicators for all other constituents were almost always achieved. Therefore, we do not recommend any changes to field, analysis, or quality assurance methods in the future.

3.0 SEDIMENT

3.1 INTRODUCTION

No specific remediation performance standards were established within the CFROU ROD for concentrations of COC metals in instream sediments [USEPA, 2004]. In lieu of performance standards the "threshold effect concentration" (TEC) and "probable effect concentration" (PEC) consensus-based sediment quality guidelines for benthic organisms [MacDonald et al., 2000], provide useful reference values for instream sediment quality (Table 3-1). At metal COC concentrations above the TEC, benthic organisms may be affected by that COC. At metal COC concentrations above the PEC, benthic organisms are likely to be affected by that COC.

Remedial actions to remove floodplain tailings deposits and reduce streambank erosion within the CFROU are expected to result in reduced COC concentrations in instream sediments within the Clark Fork River. Therefore, instream sediment COC concentrations will be monitored in the CFROU prior to, during, and following remediation. This report reviews spatial and temporal trends in instream sediment metals concentrations in the CFROU during 2017 and prior monitoring years.

Table 3-1. Reference values for contaminant of concern (COC) concentrations (expressed as dry weight concentrations [DW]) in instream sediments within the Clark Fork River Operable Unit. The threshold effect concentration (TEC) and probable effect concentration (PEC) were described in MacDonald et al. [2000].

Contaminant of Concern	Threshold Effect Concentration (mg/kg-DW)	Probable Effect Concentration (mg/kg-DW)
Arsenic	9.79	33.0
Cadmium	0.99	4.98
Copper	31.6	149
Lead	35.8	128
Zinc	121	459

3.2 METHODS

3.2.1 Monitoring Locations

Instream sediment was monitored at 14 CFROU sites in 2017 (Table 3-2; Figure 3-1). The monitoring network includes six sites on the Clark Fork River mainstem and eight sites on tributary streams (Table 3-2). The monitoring site locations in 2017 were the same as the monitoring site locations in 2016. Some monitoring site changes have occurred in prior monitoring years. Please see the project sampling and analysis plan for details of those changes [RESPEC, 2017a].

Table 3-2. Instream sediment sampling locations in the Clark Fork River Operable Unit, 2016. Streamflows were measured at all sites which did not a have co-located U.S. Geological Survey streamflow gage.

Site ID	Site Location	Co-located USGS Streamflow Gage	Location (GPS coordinates, NAD 83)	
			Latitude	Longitude
Mainstem Sites				
CFR-03A	Clark Fork River near Galen	12323800	46.20877	-112.76740
CFR-07D	Clark Fork River at Galen Road	none	46.23725	-112.75302
CFR-11F	Clark Fork River at Gemback Road	none	46.26520	-112.74430
CFR-27H	Clark Fork River at Deer Lodge	12324200	46.39796	-112.74283
CFR-34	Clark Fork River at Williams-Tavenner Bridge	none	46.47119	-112.72492
CFR-116A	Clark Fork at Turah	12334550	46.82646	-113.81424
Tributary Sites				
SS-19[33]	Silver Bow Creek at Frontage Road	none	46.12247	-112.80032
SS-25	Silver Bow Creek at Warm Springs	12323750	46.18123	-112.77917
MCWC-MWB	Mill-Willow Creek at Frontage Road	none	46.12649	-112.79876
MWB-SBC	Mill-Willow Bypass near mouth	none	46.17839	-112.78270
WSC-SBC	Warm Springs Creek near mouth	12323770	46.18041	-112.78592
LC-7.5[34]	Lost Creek near mouth	12323850	46.21862	-112.77384
RTC-1.5[35]	Racetrack Creek near mouth	none	46.28395	-112.74921
LBR-CFR-02[36]	Little Blackfoot River at Beck Hill Road	none	46.53710	-112.72443

[33] In 2017, site SS-19 was sampled under the Streamside Tailings Operable Unit (SSTOU) monitoring program four times per year. This site was sampled during every sample quarter. At all other sites, sediment samples were only collected twice per year.

[34] Site LC-7 (GPS Location: 46.22665, -112.76017) was replaced by site LC-7.5 in 2013.

[35] Site RTC-1 (GPS Location: 46.28406, -112.74484) was replaced by site RTC-1.5 in 2013.

[36] Site LBR-CFR (GPS Location: 46.51964, -112.79312; co-located USGS gage: 12324590) was replaced by site LBR-CFR-02 in 2014.

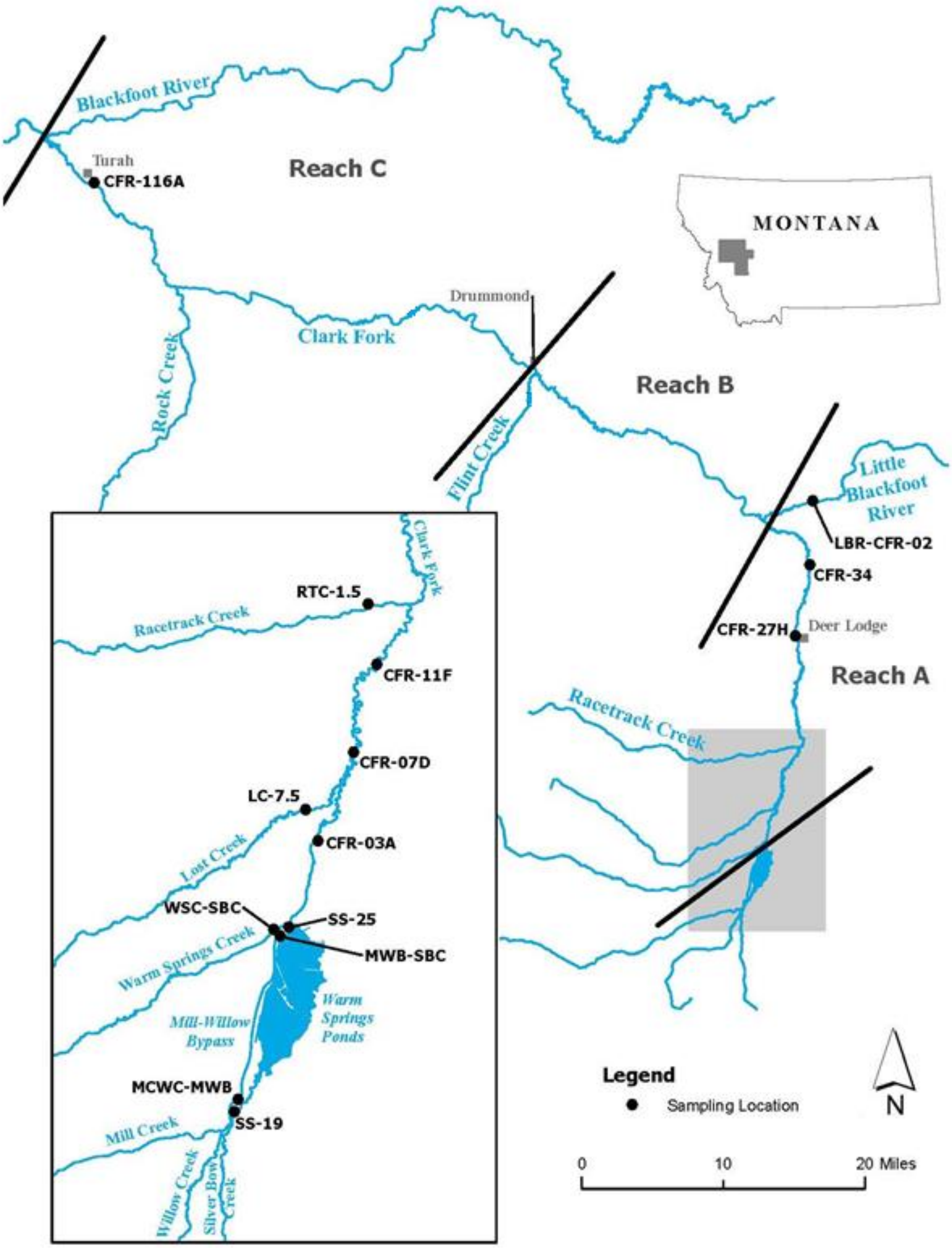

Figure 3-1. Instream sediment sampling locations in the Clark Fork River Operable Unit, 2017.

3.2.2 Monitoring Schedule

At least one surface water monitoring event occurred during each calendar quarter of 2017. Instream sediment samples were collected during the first quarter (Q1) and third quarter (Q3) surface water monitoring events. The first monitoring event (Q1) occurred in the late winter, prior to spring runoff from March 6-7. The late summer (Q3) monitoring event occurred during low streamflow conditions from September 5-6.

3.2.3 Monitoring Parameters

Instream sediment samples were analyzed for dry weight (DW) total extractable metal (arsenic, cadmium, copper, lead, and zinc) concentrations.

3.2.4 Sample Collection and Analysis

Sediment samples were collected by compositing subsamples from at least five deposition zones in wadeable locations at each monitoring site. Sediment was scooped from the streambed with a plastic spoon following the DEQ standard operating procedure [DEQ, 2012a]. The fine fraction (particle diameter <0.065 mm) portion of each sample was isolated from each composite sample by wet sieving in the laboratory shortly after collection and retained for analysis of metal concentrations. Each sample was analyzed for total extractable dry weight concentrations (mg/kg-DW) of arsenic, cadmium, copper, lead, and zinc following methods identified in Table 3-3. The relative proportion (by weight) of the fine fraction sediment in each sample was also determined. Sediment samples were analyzed by Energy Laboratories (Helena, Montana). Prior to 2013, each sediment sample was sieved into three size fractions (<0.065 mm, 0.065–1 mm, and 1–2 mm), and each size fraction was independently analyzed for metal concentrations.

Table 3-3. Analytes, methods, and reporting limits for instream sediment sampling in the Clark Fork River Operable Unit, 2017.

Analyte	Requested Method	Requested Reporting Limit (mg/kg-DW)	Holding Time (days)	Bottle	Preservative
Total Metals Digestion	EPA 3050	-	-	-	-
Arsenic	SW 6010B	5	180	1000 mL clear glass wide mouth jars	4 ± 2 °C during shipment; -15 C in laboratory
Cadmium	SW 6010B	0.2			
Copper	SW 6010B	5			
Lead	SW 6010B	5			
Zinc	SW 6010B	5			

3.2.5 Data Analysis

Data were analyzed to assess spatial and temporal trends in sediment COC concentrations (for all samples collected during 2014-2017) and to evaluate the frequency and magnitude of TEC and PEC reference value exceedances. To evaluate spatial trends, boxplots were created for each COC at each site. Statistics summarized in each boxplot include the median (midline of each box), quartiles (ends of each box), outlier extent (whiskers which extend 1.5 times the interquartile range), and outliers (circles above or below the whiskers which are any observations more than 1.5 times the interquartile range). Boxplots were only generated for data with at least five observations. If there were fewer than five observations at a site, a circle is displayed for each observation. Scatterplots of COC concentrations at each sample site were created to provide a cursory investigation of temporal trends.

The number of samples collected since 2014 differed between sites. We included all samples collected in the CFROU since 2014 to provide the most complete perspective on sediment COC concentrations even though two sites had different overall numbers of samples. First, at site SS-19, samples were collected during all sample quarters since 2014 whereas samples were collected only twice per year (Q1 and Q3) at other sites. We included all samples in the scatterplots and boxplots from site SS-19 (and all other sites) to provide the most complete data set at each site. Please note that differences in the timing of the samples collected at SS-19 and other sites could potentially confound statistical comparisons of median COC concentrations among sample sites. Second, at Flint Creek, only one sample was collected (mistakenly) in Q1 2014. We included the results of that one sample from Flint Creek because it provides valuable information since no other sediment samples had been collected at that site. In the report, we discuss the "median" COC concentrations at Flint Creek in comparison to other sites. Please note the Flint Creek median concentration is based on a sample size of one.

3.2.6 Data Validation

Data quality objectives (DQOs) were established in the CFROU quality assurance project plan (QAPP) for "data representativeness", "comparability", "completeness", "sensitivity", "precision", "bias", and "accuracy" [Atkins, 2013]. Methods for field and laboratory quality assurance and quality control (QA/QC) procedures are also described in detail in the project QAPP. A completed QA/QC checklist, summary tables of field duplicate and field blank results, and assessments of data quality objectives are included in Appendix A.

Variability in sediment metals concentrations among samples was assessed by comparing field duplicate samples to field samples. Field duplicate samples were collected at the same location and at the same time as field samples and were processed and analyzed by the same methods. The relative percent difference (RPD) between the concentration in the field duplicate and field sample pair was determined for each metal. Two field duplicate samples were collected during each sampling event and RPD statistics were calculated for each field duplicate and field sample pair.

3.3 RESULTS

3.3.1 Sample Size Fraction

The proportion of sediment by size fraction in each 2017 CFROU sediment sample is displayed in Table 3-4.

Table 3-4. Proportion of each sample collected in the Clark Fork River Operable Unit composed of fine fraction (<0.065 mm) sediment particles, 2017.

Site ID	Site Location	Sample proportion (%)	
		Q1	Q3
Mainstem Sites			
CFR-03A	Clark Fork River near Galen	3.0	3.4
CFR-07D	Clark Fork River at Galen Road	16.0	7.2
CFR-11F	Clark Fork River at Gemback Road	2.3	2.2
CFR-27H	Clark Fork River at Deer Lodge	10.8	5.6
CFR-34	Clark Fork River at Williams-Tavenner Bridge	8.4	2.4
CFR-116A	Clark Fork River at Turah	52.6	8.3
Tributary Sites			
SS-19	Silver Bow Creek at Frontage Road	0.7	3.4
SS-25	Silver Bow Creek at Warm Springs	3.6	3.0
MCWC-MWB	Mill-Willow Creek at Frontage Road	13.9	7.1
MWB-SBC	Mill-Willow Bypass near mouth	1.5	2.1
WSC-SBC	Warm Springs Creek near mouth	13.8	24.9
LC-7.5	Lost Creek near mouth	27.9	11.5
RTC-1.5	Racetrack Creek near mouth	1.7	1.9
LBR-CFR-02	Little Blackfoot River at Beck Hill Road	2.1	1.1

3.3.2 Contaminants of Concern

3.3.2.1 Arsenic

In the Clark Fork River mainstem, fine fraction (<0.065 mm) sediment arsenic concentrations ranged from 32-299 mg/kg-DW in 2017 (Table 3-5). Exceedances of the TEC and PEC reference values occurred at all sites during both sample periods in 2017 except for Turah during Q3 (Table 3-5). Arsenic concentrations at each site were similar in 2017 compared to prior monitoring years although there appears to be a high degree of variability at some sites (particularly near Galen, Galen Road, and Gemback Road) (Figure 3-2). Given the small number of dry weight samples (i.e., ≤8), and the variability of these samples, we do not believe it is reasonable to evaluate temporal trends at these sites yet. However, longitudinally there is evidence that median sediment arsenic concentrations decrease, in approximately an exponential fashion, between Clark Fork River mainstem sites near Galen (river mile 0) and Turah (river mile 116) (Figure 3-3).

In the Clark Fork River tributaries, fine fraction (<0.065 mm) sediment arsenic concentrations ranged from 19-250 mg/kg-DW in 2017 (Table 3-5). Exceedances of the TEC, the PEC, or both reference values occurred at all sites during both sample periods in 2017 (Table 3-5) No PEC exceedances occurred in the Little Blackfoot River or in Racetrack Creek during Q3 (Table 3-5). Arsenic concentrations at each tributary site were similar in 2017 compared to prior monitoring years (Figure 3-4). Given the small number and variability of dry weight samples (i.e., ≤8), we do not believe it is reasonable to evaluate temporal trends at these sites yet. Among paired tributary sites in Silver Bow Creek (at Frontage Road and at Warm Springs) and Mill-Willow Creek (at Frontage Road and near mouth), median arsenic concentrations over the 2014-2017 period were about twice as high in Silver Bow Creek at the downstream site (at Warm Springs) and about twice as high in Mill-Willow Creek at the downstream site (near mouth) (Figure 3-5). Among tributaries, the lowest median arsenic concentrations for 2014-2017 were in Racetrack Creek and the Little Blackfoot River (Figure 3-5).

Table 3-5. Total arsenic concentrations (mg/kg dry weight) in fine fraction (<0.065 mm) instream sediment samples from the Clark Fork River Operable Unit, 2017.

Site ID	Site Location	Sample concentration (mg/kg-DW)	
		Q1	Q3
Mainstem Sites			
CFR-03A	Clark Fork River near Galen	230	126
CFR-07D	Clark Fork River at Galen Road	217	299
CFR-11F	Clark Fork River at Gemback Road	239	108
CFR-27H	Clark Fork River at Deer Lodge	159	143
CFR-34	Clark Fork River at Williams-Tavenner Bridge	167	98
CFR-116A	Clark Fork River at Turah	61	32
Tributary Sites			
SS-19	Silver Bow Creek at Frontage Road	71	67
SS-25	Silver Bow Creek at Warm Springs	148	127
MCWC-MWB	Mill-Willow Creek at Frontage Road	118	102
MWB-SBC	Mill-Willow Bypass near mouth	149	250
WSC-SBC	Warm Springs Creek near mouth	94	92
LC-7.5	Lost Creek near mouth	87	68
RTC-1.5	Racetrack Creek near mouth	37	25
LBR-CFR-02	Little Blackfoot River at Beck Hill Road	25	19

(yellow)	Exceeds threshold effect concentration, 9.79 mg/kg [MacDonald et al., 2000].
(red)	Exceeds probable effect concentration, 33.0 mg/kg [MacDonald et al., 2000].

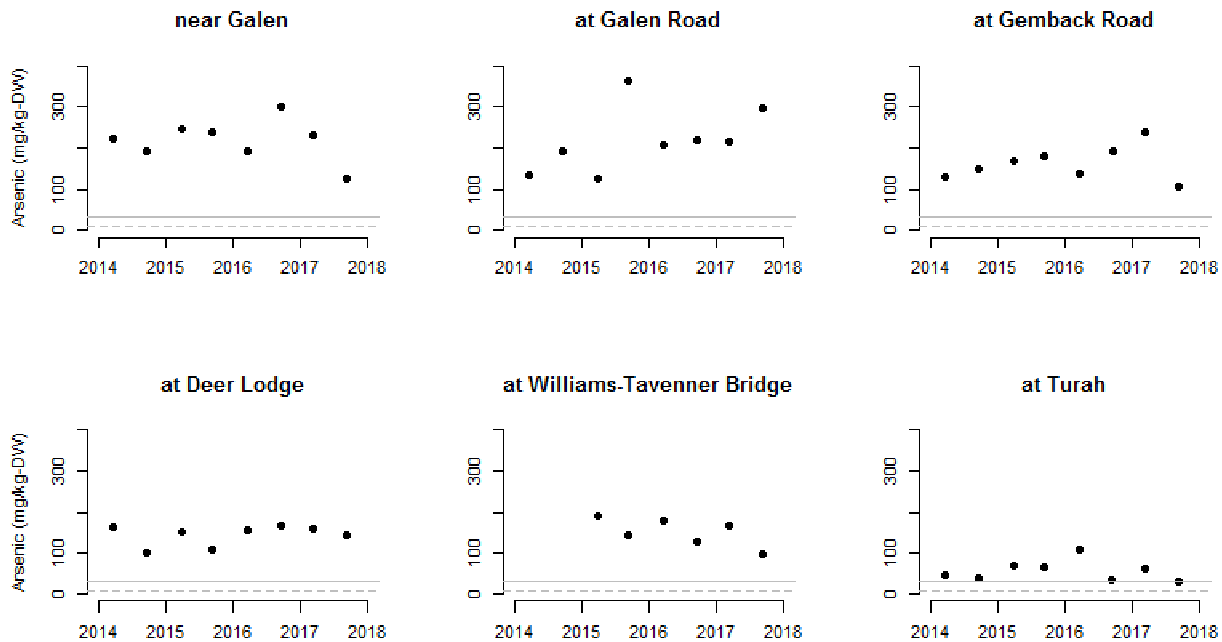

Figure 3-2. Time series of total arsenic concentrations (dry weight) at each Clark Fork River mainstem monitoring site, 2014-2017. Horizontal lines represent the “threshold effect concentration” (TEC; dashed line) at 9.79 mg/kg and the “probable effect concentration” (PEC; solid line) at 33.0 mg/kg [MacDonald et al., 2000].

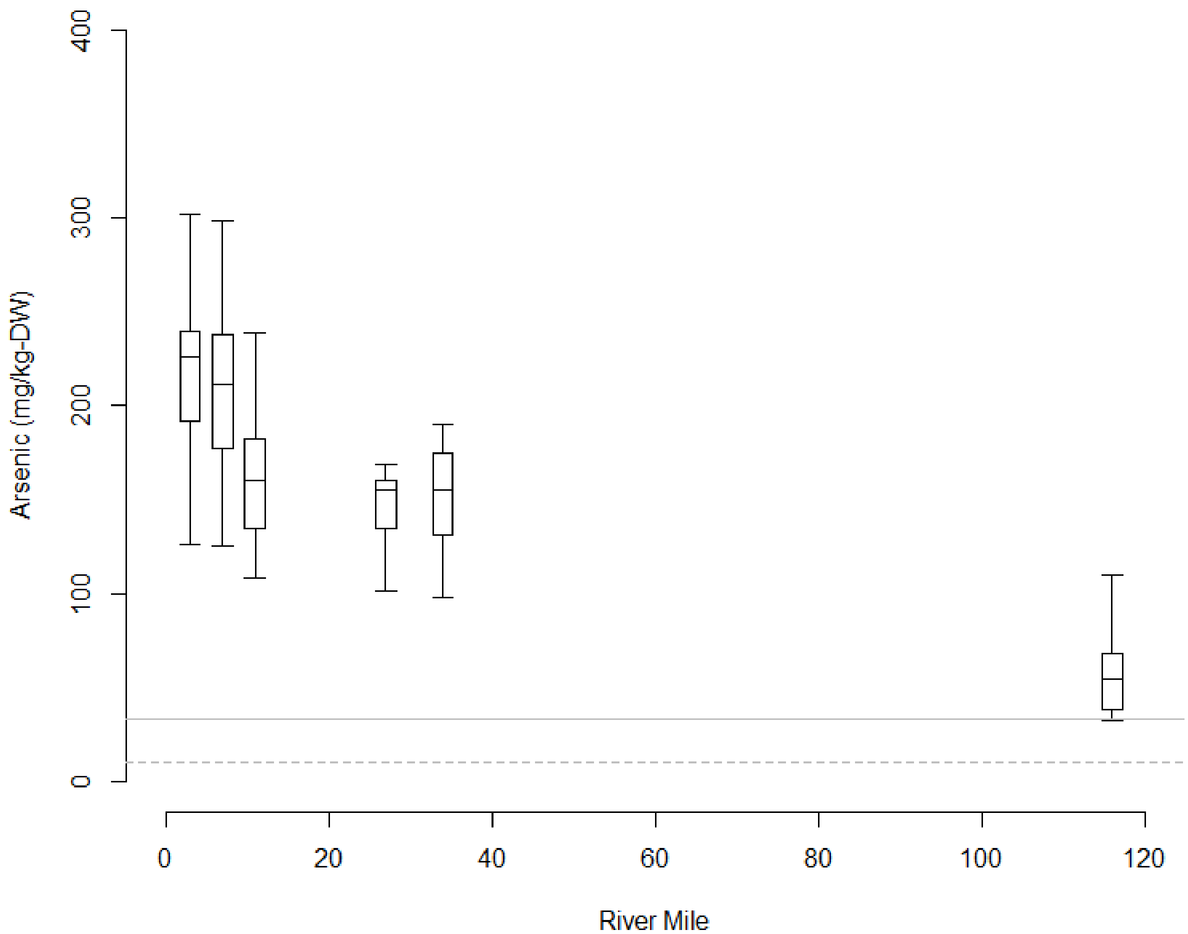

Figure 3-3. Boxplots of total arsenic concentration (dry weight) at each Clark Fork River mainstem monitoring site, 2014-2017. River miles are measured downstream from the Silver Bow Creek-Warm Springs Creek confluence. Horizontal lines represent the "threshold effect concentration" (TEC; dashed line) at 9.79 mg/kg and the "probable effect concentration" (PEC; solid line) at 33.0 mg/kg [MacDonald et al., 2000].

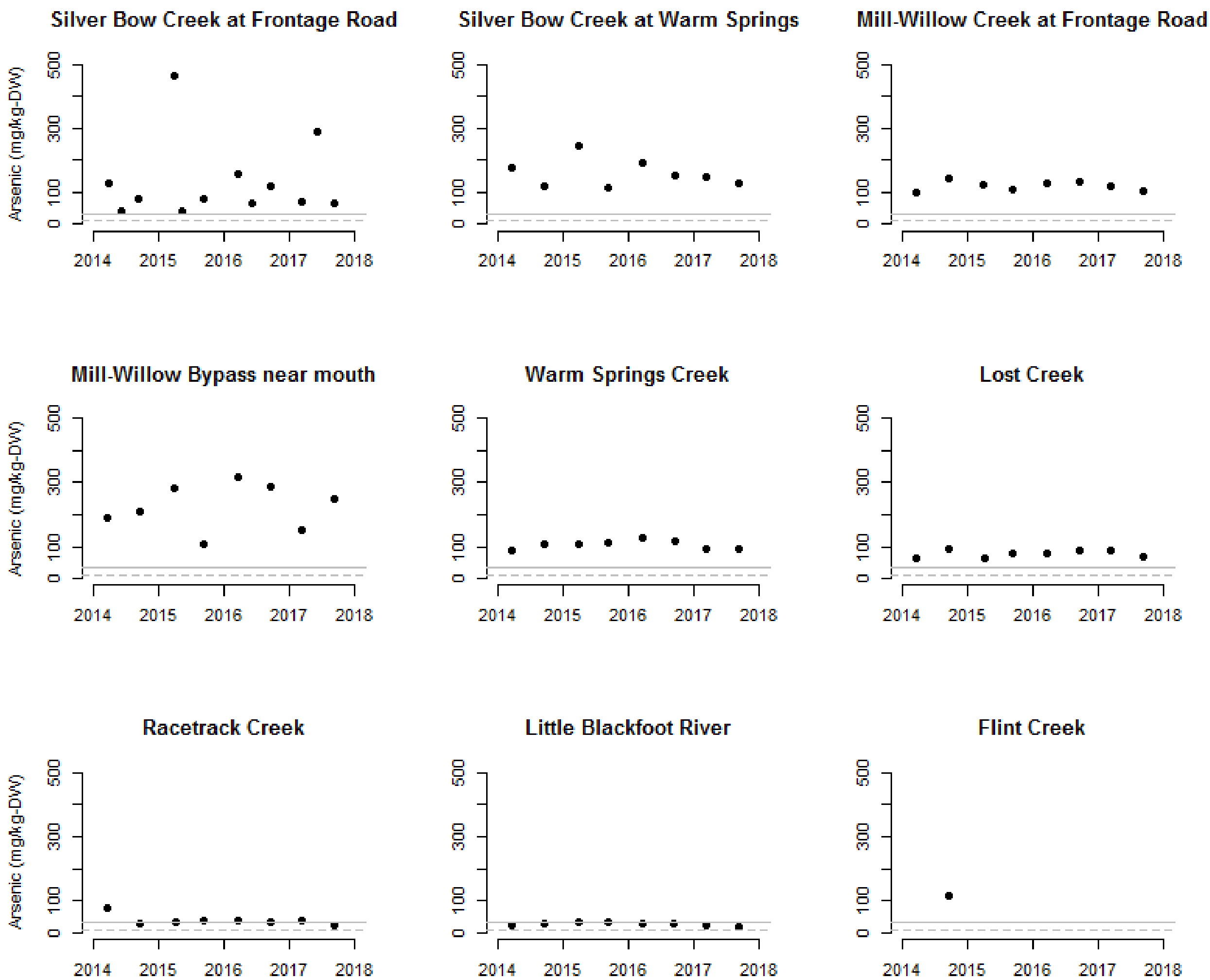

Figure 3-4. Time series of total arsenic concentrations (dry weight) in tributaries of the Clark Fork River, 2014-2017. Horizontal lines represent the “threshold effect concentration” (TEC; dashed line) at 9.79 mg/kg and the “probable effect concentration” (PEC; solid line) at 33.0 mg/kg [MacDonald et al., 2000].

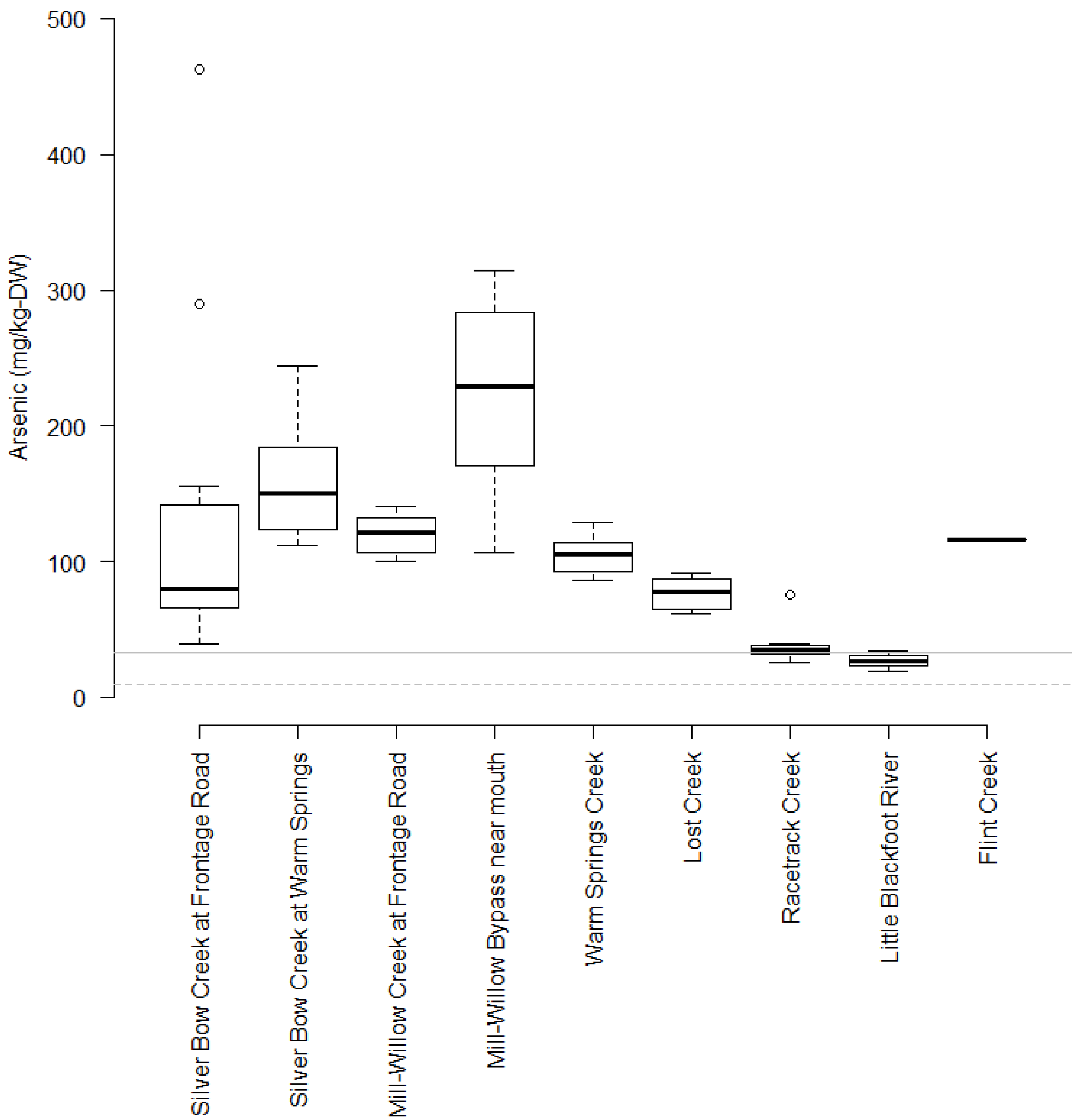

Figure 3-5. Boxplots of total arsenic concentration (dry weight) in Clark Fork River tributary monitoring sites, 2014-2017. Horizontal lines represent the "threshold effect concentration" (TEC; dashed line) at 9.79 mg/kg and the "probable effect concentration" (PEC; solid line) at 33.0 mg/kg [MacDonald et al., 2000].

3.3.2.2 Cadmium

In the Clark Fork River mainstem, fine fraction (<0.065 mm) sediment cadmium concentrations ranged from 4.0-11.8 mg/kg-DW in 2017 (Table 3-6). Exceedances of the TEC and PEC reference values occurred at all sites during both sample periods in 2017 with two exceptions. Only the TEC was exceeded during Q1 at CFR-27H (at Deer Lodge), and during both sample periods at CFR-116A (at Turah) (Table 3-6). Cadmium concentrations at each site were similar in 2017 compared to prior monitoring years (Figure 3-6). Given the small number and variability of dry weight samples (i.e., ≤8), we do not believe temporal trends can be seen at these sites yet. Longitudinally on the Clark Fork River mainstem, there is a slight declining trend in median sediment cadmium concentrations between near Galen (river mile 0) and Turah (river mile 116) with the exception of the Williams-Tavenner Bridge site (river mile 34) where concentrations appear to be locally elevated (Figure 3-7).

In the Clark Fork River tributaries, fine fraction (<0.065 mm) sediment cadmium concentrations ranged from 1.2-7.6 mg/kg-DW in 2017 (Table 3-6). Exceedances of the cadmium TEC occurred in all tributary sites in both sample periods of 2017, but PEC exceedances occurred only at Silver Bow Creek, Mill-Willow Creek, and Warm Springs Creek (Table 3-6). Cadmium concentrations in most tributary sites were similar in 2017 to prior monitoring years, although at some sites cadmium concentrations have been highly variable, particularly the Silver Bow Creek sites (Figure 3-8). Given the small number and variability of dry weight samples (i.e., ≤8), we do not believe temporal trends can be seen at these sites yet. Among paired tributary sites in Silver Bow Creek (at Frontage Road and at Warm Springs), median cadmium concentrations for the 2014-2017 period were about 50 percent higher above the Warm Springs Ponds (at Frontage Road) compared to downstream from the ponds (at Warm Springs) (Figure 3-9). However, median cadmium concentrations were similar between sites on Mill-Willow Creek (Figure 3-9). Median cadmium concentrations in Lost Creek, Racetrack Creek, the Little Blackfoot River, and Flint Creek have been well below the PEC since 2014 (Figure 3-9).

Table 3-6. Total cadmium concentrations (mg/kg dry weight) in fine fraction (<0.065 mm) instream sediment samples from the Clark Fork River Operable Unit, 2017.

Site ID	Site Location	Sample concentration (mg/kg-WW)	
		Q1	Q3
Mainstem Sites			
CFR-03A	Clark Fork River near Galen	10.3	7.5
CFR-07D	Clark Fork River at Galen Road	5.7	9.4
CFR-11F	Clark Fork River at Gemback Road	8.2	8.3
CFR-27H	Clark Fork River at Deer Lodge	4.9	5.9
CFR-34	Clark Fork River at Williams-Tavenner Bridge	10.2	11.8
CFR-116A	Clark Fork River at Turah	4.5	4.0
Tributary Sites			
SS-19	Silver Bow Creek at Frontage Road	8.3	10.0
SS-25	Silver Bow Creek at Warm Springs	7.6	7.4
MCWC-MWB	Mill-Willow Creek at Frontage Road	5.4	5.6
MWB-SBC	Mill-Willow Bypass near mouth	4.5	6.4
WSC-SBC	Warm Springs Creek near mouth	5.1	4.2
LC-7.5	Lost Creek near mouth	3.9	2.9
RTC-1.5	Racetrack Creek near mouth	2.7	1.5
LBR-CFR-02	Little Blackfoot River at Beck Hill Road	1.2	3.5

Exceeds threshold effect concentration, 0.99 mg/kg [MacDonald et al., 2000].

Exceeds probable effect concentration, 4.98 mg/kg [MacDonald et al., 2000].

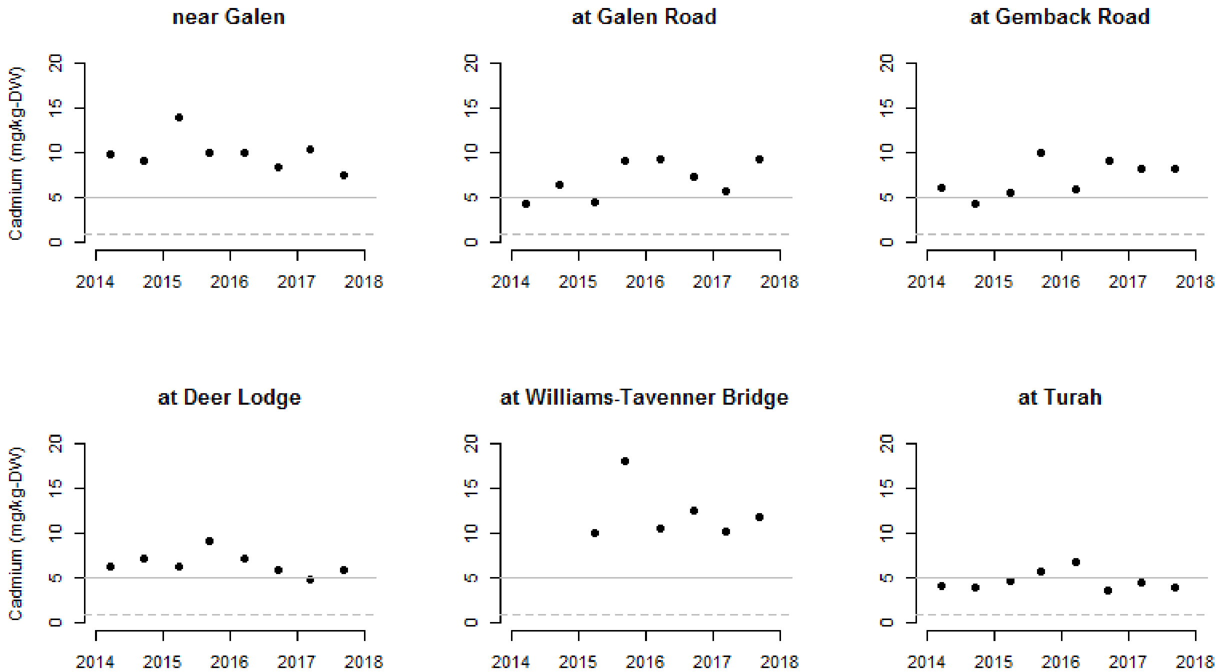

Figure 3-6. Time series of total cadmium concentrations (dry weight) at each Clark Fork River mainstem monitoring site, 2014-2017. Horizontal lines represent the "threshold effect concentration" (TEC; dashed line) at 0.99 mg/kg and the "probable effect concentration" (PEC; solid line) at 4.98 mg/kg [MacDonald et al., 2000].

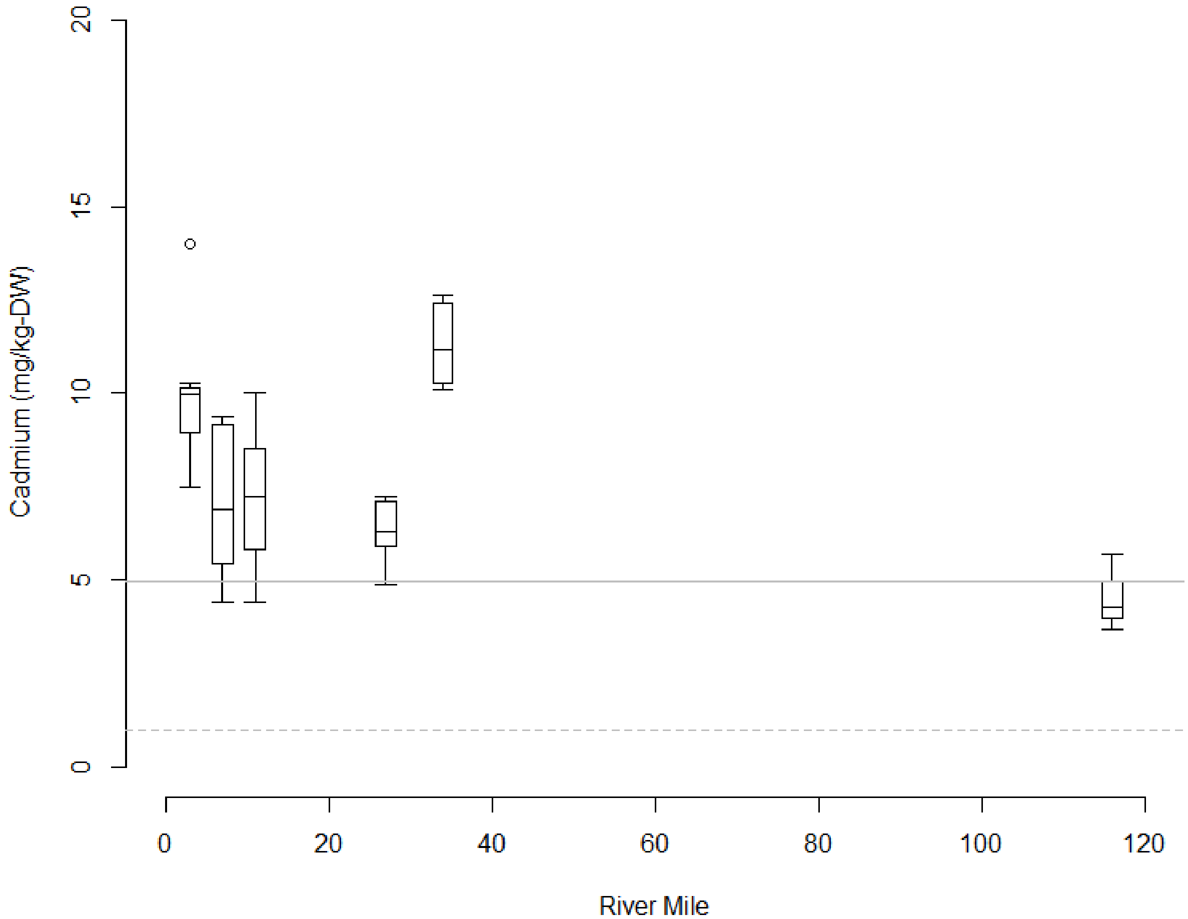

Figure 3-7. Boxplots of total cadmium concentration (dry weight) at each Clark Fork River mainstem monitoring site, 2014-2017. River miles are measured downstream from the Silver Bow Creek-Warm Springs Creek confluence. Horizontal lines represent the "threshold effect concentration" (TEC; dashed line) at 0.99 mg/kg and the "probable effect concentration" (PEC; solid line) at 4.98 mg/kg [MacDonald et al., 2000].

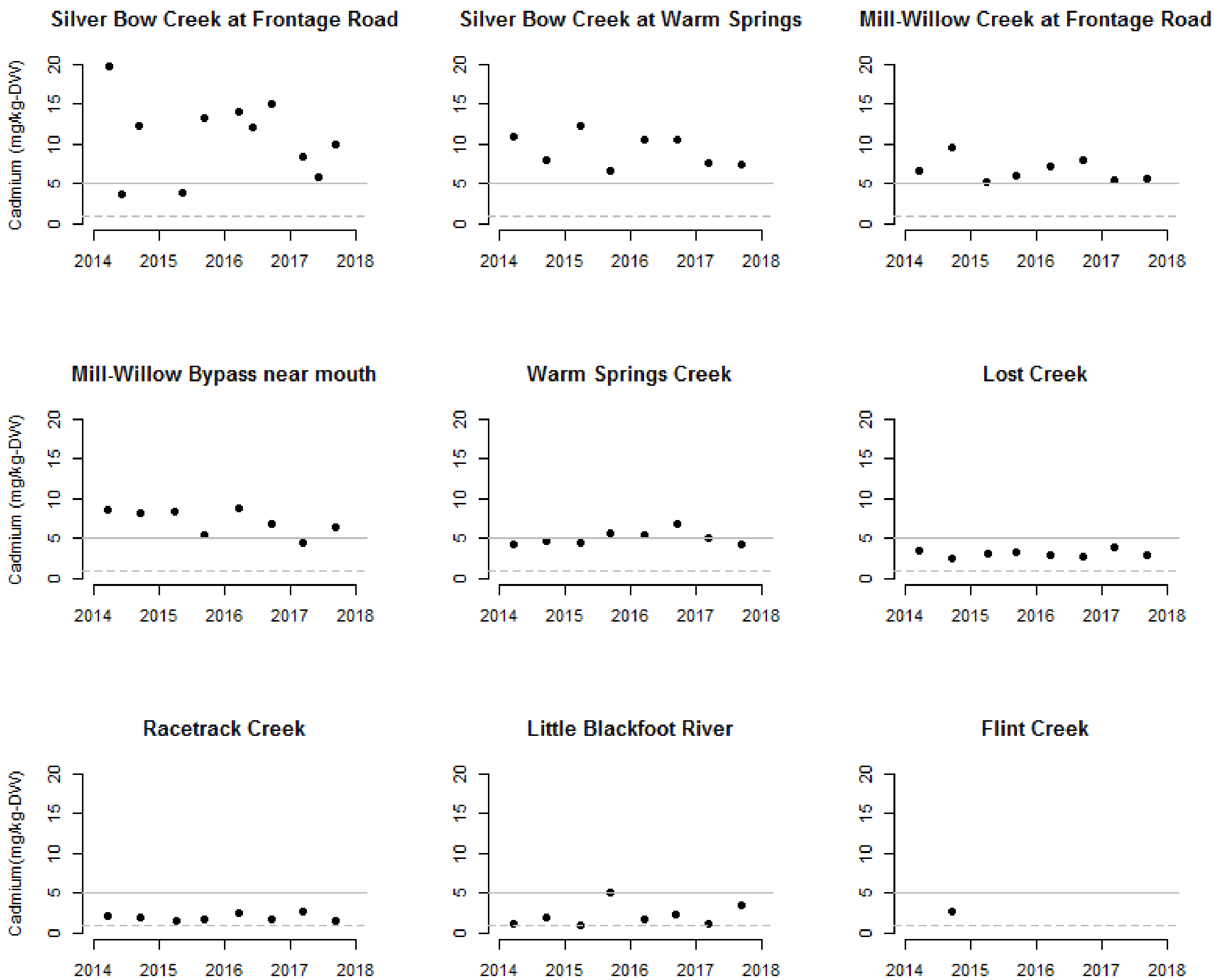

Figure 3-8. Time series of total cadmium concentrations (dry weight) in tributaries of the Clark Fork River, 2014-2017[37]. Horizontal lines represent the "threshold effect concentration" (TEC; dashed line) at 0.99 mg/kg and the "probable effect concentration" (PEC; solid line) at 4.98 mg/kg [MacDonald et al., 2000].

[37] One sample from the Silver Bow Creek at Frontage Road site collected on March 26, 2015 had an unusually high cadmium concentration (97 mg/kg-DW) and is not displayed.

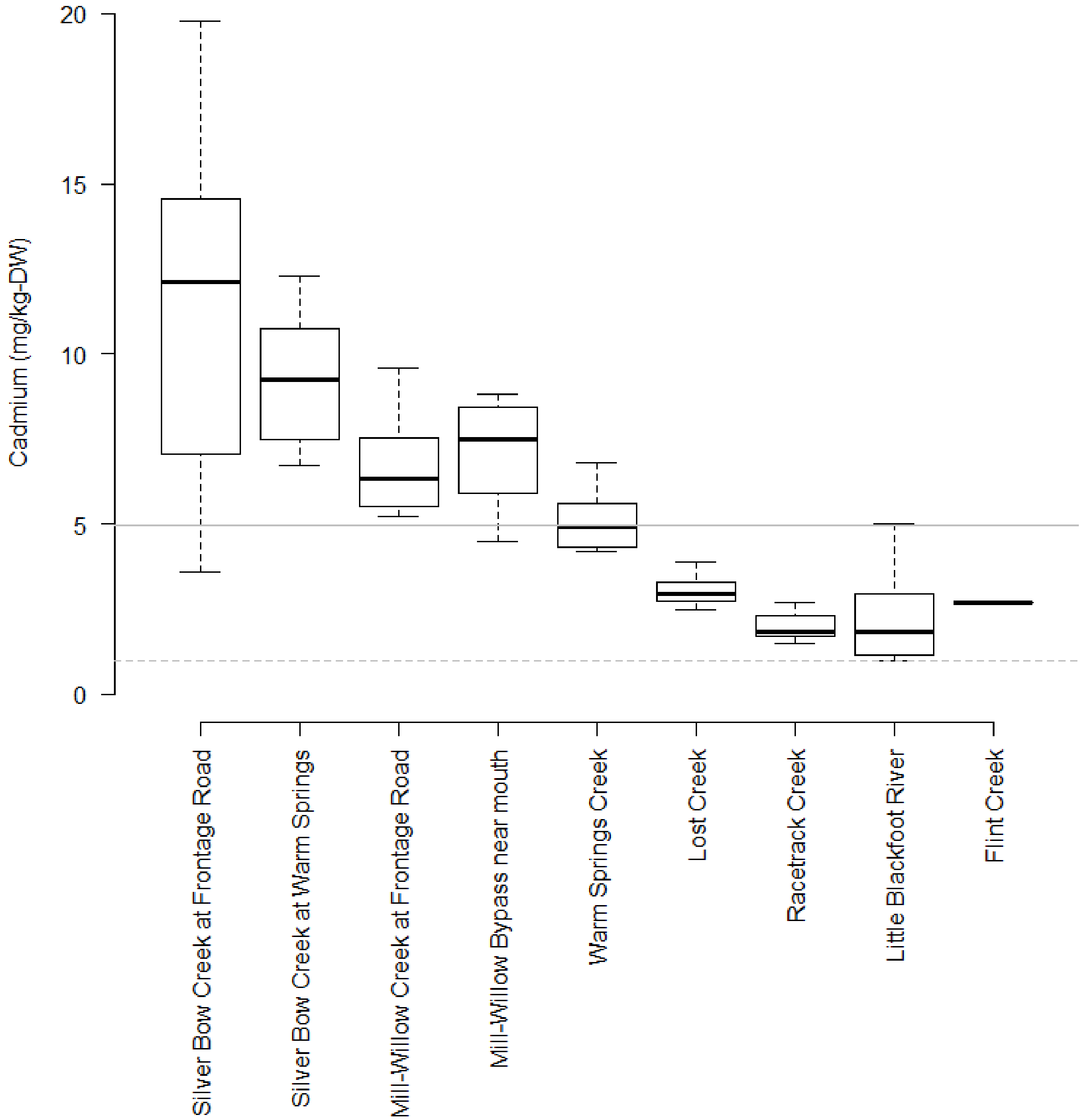

Figure 3-9. Boxplots of total cadmium concentration (dry weight) in Clark Fork River tributary monitoring sites, 2014-2017[38]. Horizontal lines represent the "threshold effect concentration" (TEC; dashed line) at 0.99 mg/kg and the "probable effect concentration" (PEC; solid line) at 4.98 mg/kg [MacDonald et al., 2000].

[38] One sample from the Silver Bow Creek at Frontage Road site collected on March 26, 2015 had an unusually high cadmium concentration (97 mg/kg-DW) and is not displayed.

3.3.2.3 Copper

In the Clark Fork River mainstem, fine fraction (<0.065 mm) sediment copper concentrations ranged from 531-2,840 mg/kg-DW in 2017 (Table 3-7). Exceedances of the TEC and PEC reference values occurred at all sites during both sample periods in 2017 (Table 3-7). Copper concentrations at each site were generally similar in 2017 compared to prior monitoring years (Figure 3-10). Given the small number and variability of dry weight samples (i.e., ≤8) collected to date at these sites, we do not believe temporal trends can be seen at these sites yet. Longitudinally on the Clark Fork River mainstem, there is a declining trend in median sediment copper concentrations between near Galen (river mile 0) and Turah (river mile 116) with the exception of the Williams-Tavenner Bridge site (river mile 34) where concentrations appear to be locally elevated (Figure 3-3).

In the Clark Fork River tributaries, fine fraction (<0.065 mm) sediment copper concentrations ranged from 49-1,160 mg/kg-DW in 2017 (Table 3-7). Exceedances of the copper TEC and PEC occurred in all tributary sites except Racetrack Creek and the Little Blackfoot River (Table 3-7). In Racetrack Creek and the Little Blackfoot River, all samples exceeded the TEC in 2017 (Table 3-7). Copper concentrations in most tributary sites were similar in 2017 to prior monitoring years, although the Silver Bow Creek at Frontage Road copper concentrations have been quite variable (Figure 3-12). Given the small number and variability of dry weight samples (i.e., ≤8), we do not believe temporal trends can be seen at these sites yet. Among paired tributary sites in Silver Bow Creek, median copper concentrations for 2014-2017 were about twice as high in Silver Bow Creek upstream from the ponds (at Frontage Road) compared to the site below the Warm Springs Ponds (at Warm Springs) (Figure 3-13). In Mill-Willow Creek, 2014-2017 median copper concentrations were higher at the upstream site (Figure 3-13). Median copper concentrations in Racetrack Creek, the Little Blackfoot River, and Flint Creek have been below the PEC since 2014 (Figure 3-13). The highest median copper concentrations in sediments since 2014 have occurred in Warm Springs Creek (Figure 3-13).

Table 3-7. Total copper concentrations (mg/kg dry weight) in fine fraction (<0.065 mm) instream sediment samples from the Clark Fork River Operable Unit, 2017.

Site ID	Site Location	Sample concentration (mg/kg-DW)	
		Q1	Q3
Mainstem Sites			
CFR-03A	Clark Fork River near Galen	1790	2160
CFR-07D	Clark Fork River at Galen Road	1930	2840
CFR-11F	Clark Fork River at Gemback Road	1560	1280
CFR-27H	Clark Fork River at Deer Lodge	1300	1530
CFR-34	Clark Fork River at Williams-Tavenner Bridge	1920	1490
CFR-116A	Clark Fork River at Turah	633	531
Tributary Sites			
SS-19	Silver Bow Creek at Frontage Road	671	575
SS-25	Silver Bow Creek at Warm Springs	524	382
MCWC-MWB	Mill-Willow Creek at Frontage Road	413	363
MWB-SBC	Mill-Willow Bypass near mouth	259	227
WSC-SBC	Warm Springs Creek near mouth	904	1160
LC-7.5	Lost Creek near mouth	603	465
RTC-1.5	Racetrack Creek near mouth	143	63
LBR-CFR-02	Little Blackfoot River at Beck Hill Road	49	170

Yellow: Exceeds threshold effect concentration, 31.6 mg/kg [MacDonald et al., 2000].
Red: Exceeds probable effect concentration, 149 mg/kg [MacDonald et al., 2000].

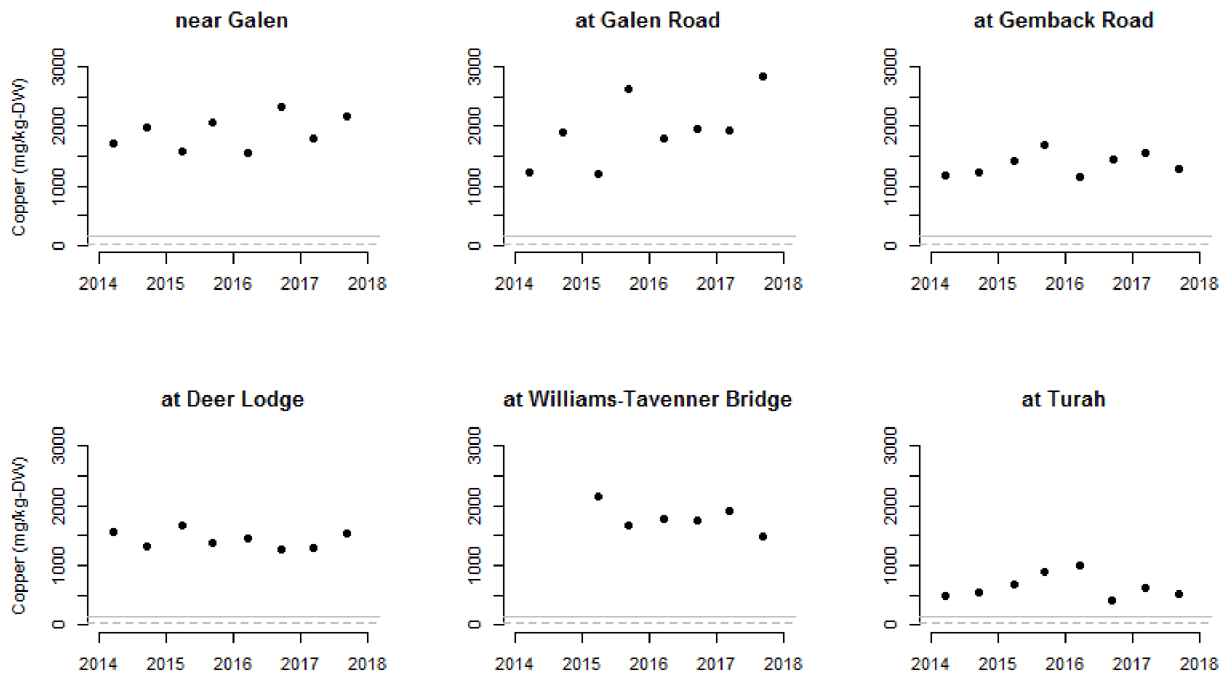

Figure 3-10. Time series of total copper concentrations (dry weight) at each Clark Fork River mainstem monitoring site, 2014-2017. Horizontal lines represent the "threshold effect concentration" (TEC; dashed line) at 31.6 mg/kg and the "probable effect concentration" (PEC; solid line) at 149 mg/kg [MacDonald et al., 2000].

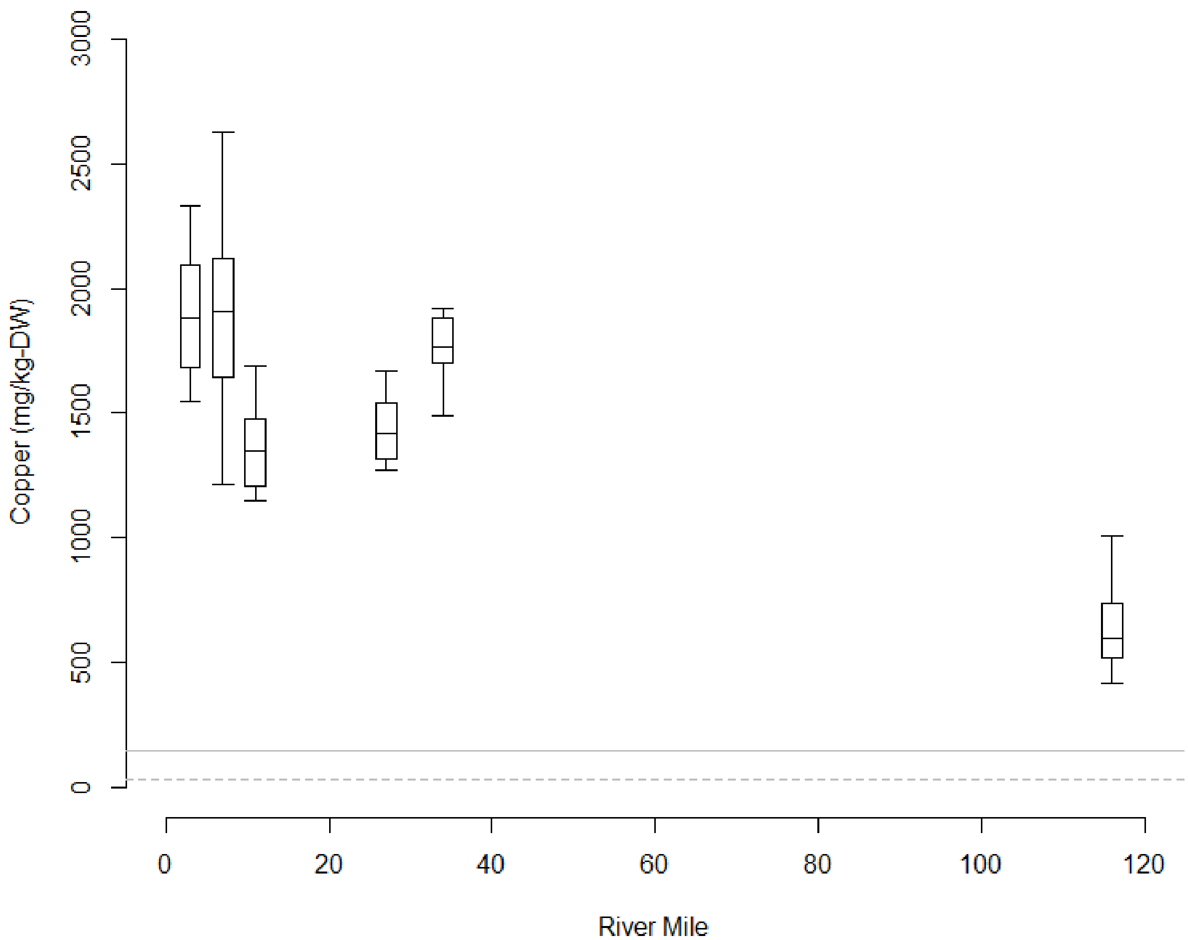

Figure 3-11. Boxplots of total copper concentration (dry weight) at each Clark Fork River mainstem monitoring site, 2014-2017. River miles are measured downstream from the Silver Bow Creek-Warm Springs Creek confluence. Horizontal lines represent the "threshold effect concentration" (TEC; dashed line) at 31.6 mg/kg and the "probable effect concentration" (PEC; solid line) at 149 mg/kg [MacDonald et al., 2000].

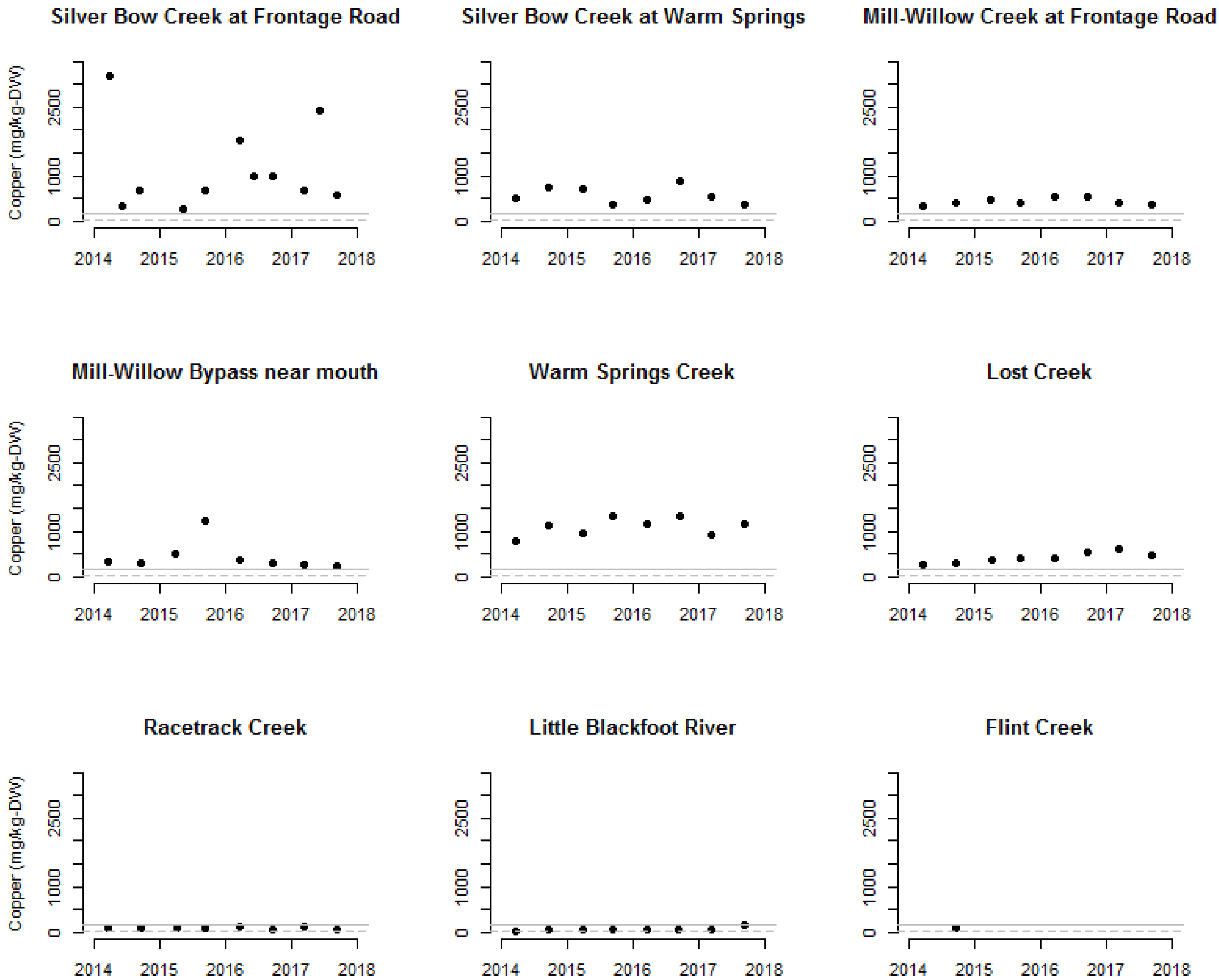

Figure 3-12. Time series of total copper concentrations (dry weight) in tributaries of the Clark Fork River, 2014-2017[39]. Horizontal lines represent the "threshold effect concentration" (TEC; dashed line) at 31.6 mg/kg and the "probable effect concentration" (PEC; solid line) at 149 mg/kg [MacDonald et al., 2000].

[39] One sample from the Silver Bow Creek at Frontage Road site collected on March 26, 2015 had an unusually high copper concentration (35,700 mg/kg-DW) and is not displayed.

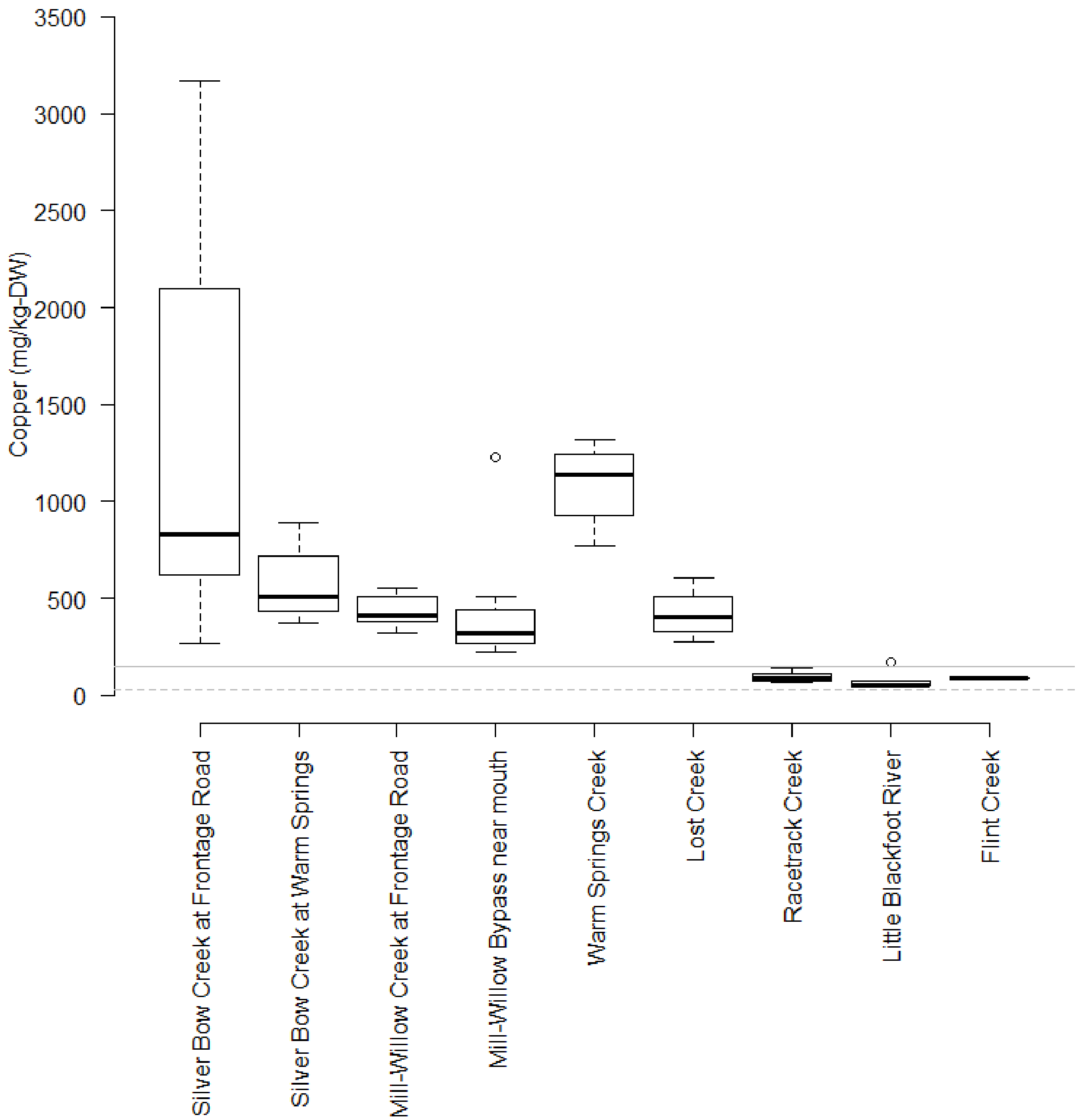

Figure 3-13. Boxplots of total copper concentration (dry weight) in Clark Fork River tributary monitoring sites, 2014-2017[40]. Horizontal lines represent the "threshold effect concentration" (TEC; dashed line) at 31.6 mg/kg and the "probable effect concentration" (PEC; solid line) at 149 mg/kg [MacDonald et al., 2000].

[40] One sample from the Silver Bow Creek at Frontage Road site collected on March 26, 2015 had an unusually high copper concentration (35,700 mg/kg-DW) and is not displayed.

3.3.2.4 Lead

In the Clark Fork River mainstem, fine fraction (<0.065 mm) sediment lead concentrations ranged from 110-422 mg/kg-DW in 2017 (Table 3-8). Exceedances of the TEC and PEC reference values occurred at all sites during both sample periods in 2017 (Table 3-8), except at Turah where only the TEC was exceeded. Lead concentrations at each site were similar in 2017 compared to prior monitoring years (Figure 3-14). Given the small number and variability of dry weight samples (i.e., ≤8) collected to date at these sites, we do not believe temporal trends can be seen at these sites yet. Longitudinally on the Clark Fork River mainstem, there is a slight declining trend in median sediment lead concentrations between sites near Galen (river mile 0) and Turah (river mile 116) except for the Williams-Tavenner Bridge site (river mile 34) where concentrations appear to be locally elevated (Figure 3-15).

In the Clark Fork River tributaries, fine fraction (<0.065 mm) sediment lead concentrations ranged from 75-184 mg/kg-DW in 2017 (Table 3-8). Exceedances of the lead PEC occurred in 2017 tributary samples for Silver Bow Creek, Mill-Willow Creek, and Warm Springs Creek. All tributary samples exceeded the lead TEC (Table 3-8). Lead concentrations in most tributary sites were similar in 2017 compared to prior monitoring years, although at some sites lead concentrations have been highly variable, particularly the Silver Bow Creek sites (Figure 3-16). Given the small number and variability of dry weight samples (i.e., ≤8), we do not believe temporal trends can be seen at these sites yet. Among paired tributary sites in Silver Bow Creek and Mill-Willow Creek, lead concentrations were similar (Figure 3-17). The lowest median lead concentrations occurred in the Little Blackfoot River (Figure 3-17).

Table 3-8. Total lead concentrations (mg/kg dry weight) in fine fraction (<0.065 mm) instream sediment samples from the Clark Fork River Operable Unit, 2017.

Site ID	Site Location	Sample concentration (mg/kg-WW)	
		Q1	Q3
Mainstem Sites			
CFR-03A	Clark Fork River near Galen	205	195
CFR-07D	Clark Fork River at Galen Road	281	422
CFR-11F	Clark Fork River at Gemback Road	333	222
CFR-27H	Clark Fork River at Deer Lodge	224	249
CFR-34	Clark Fork River at Williams-Tavenner Bridge	297	239
CFR-116A	Clark Fork River at Turah	120	110
Tributary Sites			
SS-19	Silver Bow Creek at Frontage Road	501	528
SS-25	Silver Bow Creek at Warm Springs	184	160
MCWC-MWB	Mill-Willow Creek at Frontage Road	140	157
MWB-SBC	Mill-Willow Bypass near mouth	118	169
WSC-SBC	Warm Springs Creek near mouth	126	129
LC-7.5	Lost Creek near mouth	81	95
RTC-1.5	Racetrack Creek near mouth	75	94
LBR-CFR-02	Little Blackfoot River at Beck Hill Road	93	115

(yellow) Exceeds threshold effect concentration, 35.8 mg/kg [MacDonald et al., 2000].
(red) Exceeds probable effect concentration, 128 mg/kg [MacDonald et al., 2000].

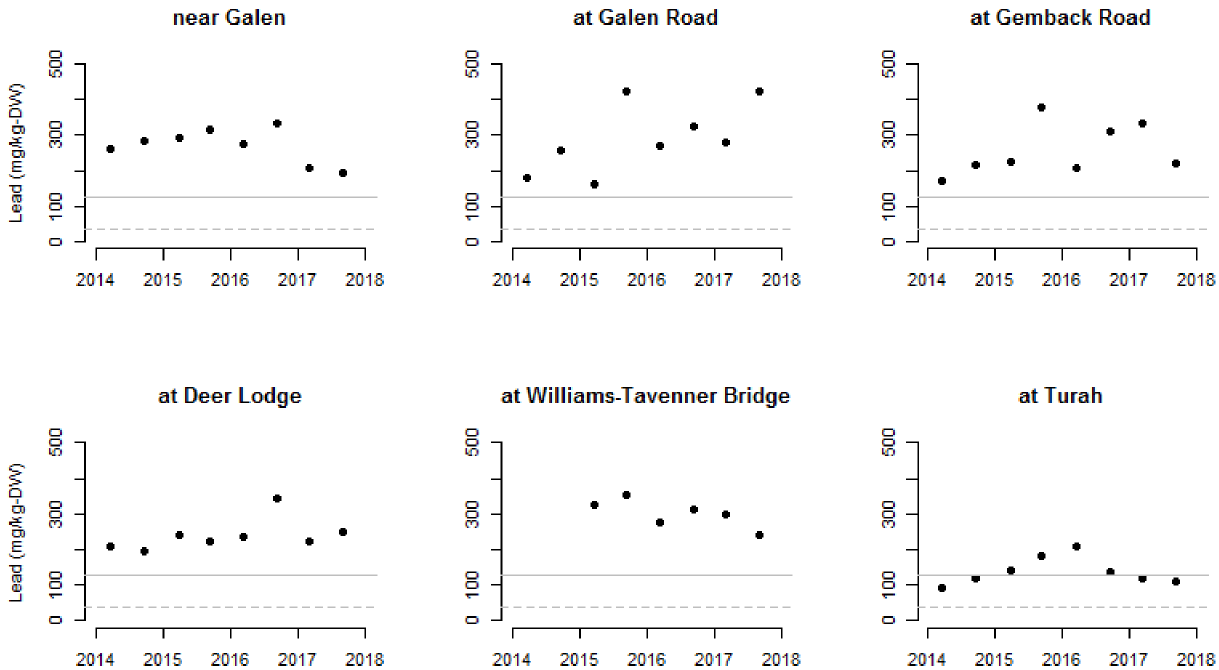

Figure 3-14. Time series of total lead concentrations (dry weight) at each Clark Fork River mainstem monitoring site, 2014-2017. Horizontal lines represent the "threshold effect concentration" (TEC; dashed line) at 35.8 mg/kg and the "probable effect concentration" (PEC; solid line) at 128 mg/kg [MacDonald et al., 2000].

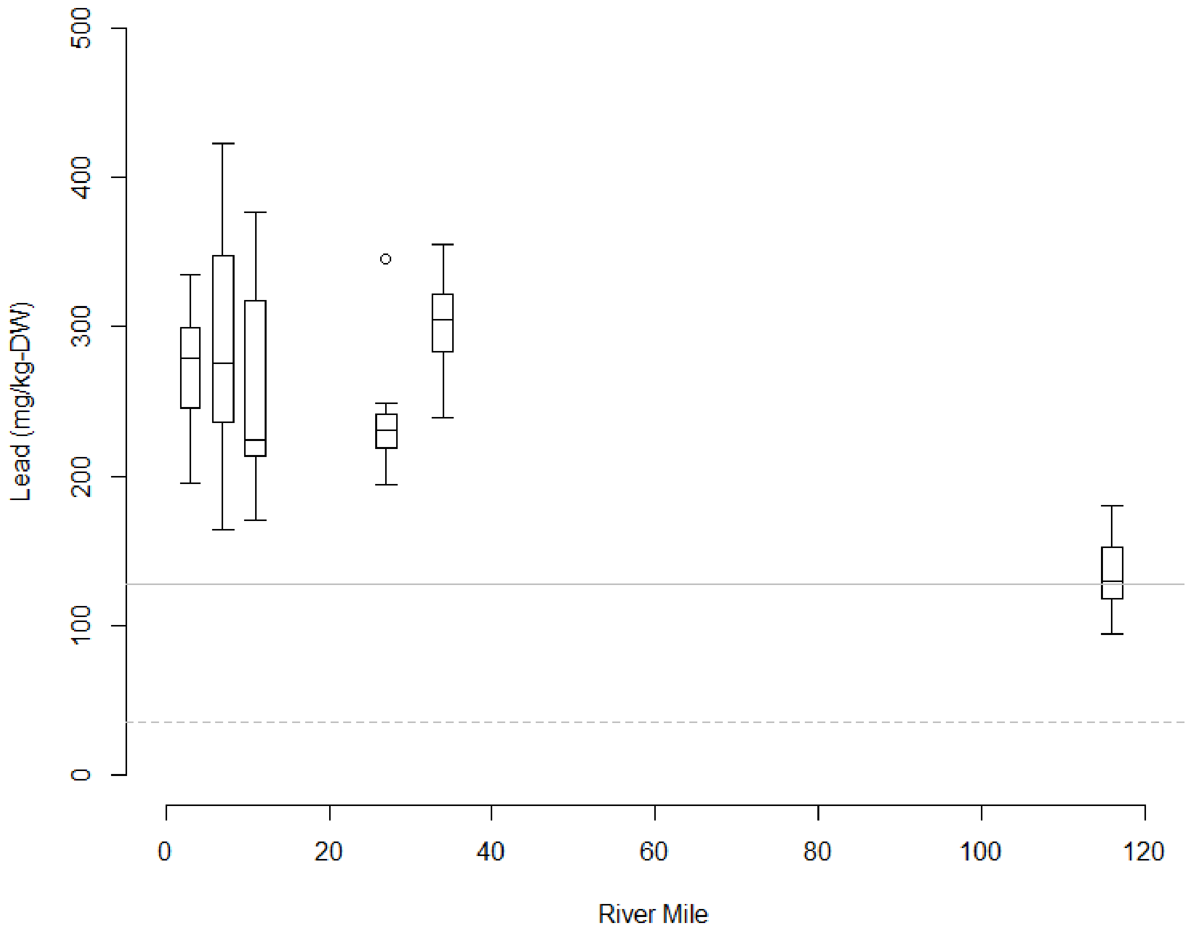

Figure 3-15. Boxplots of total lead concentration (dry weight) at each Clark Fork River mainstem monitoring site, 2014-2017. River miles are measured downstream from the Silver Bow Creek-Warm Springs Creek confluence. Horizontal lines represent the “threshold effect concentration” (TEC; dashed line) at 35.8 mg/kg and the “probable effect concentration” (PEC; solid line) at 128 mg/kg [MacDonald et al., 2000].

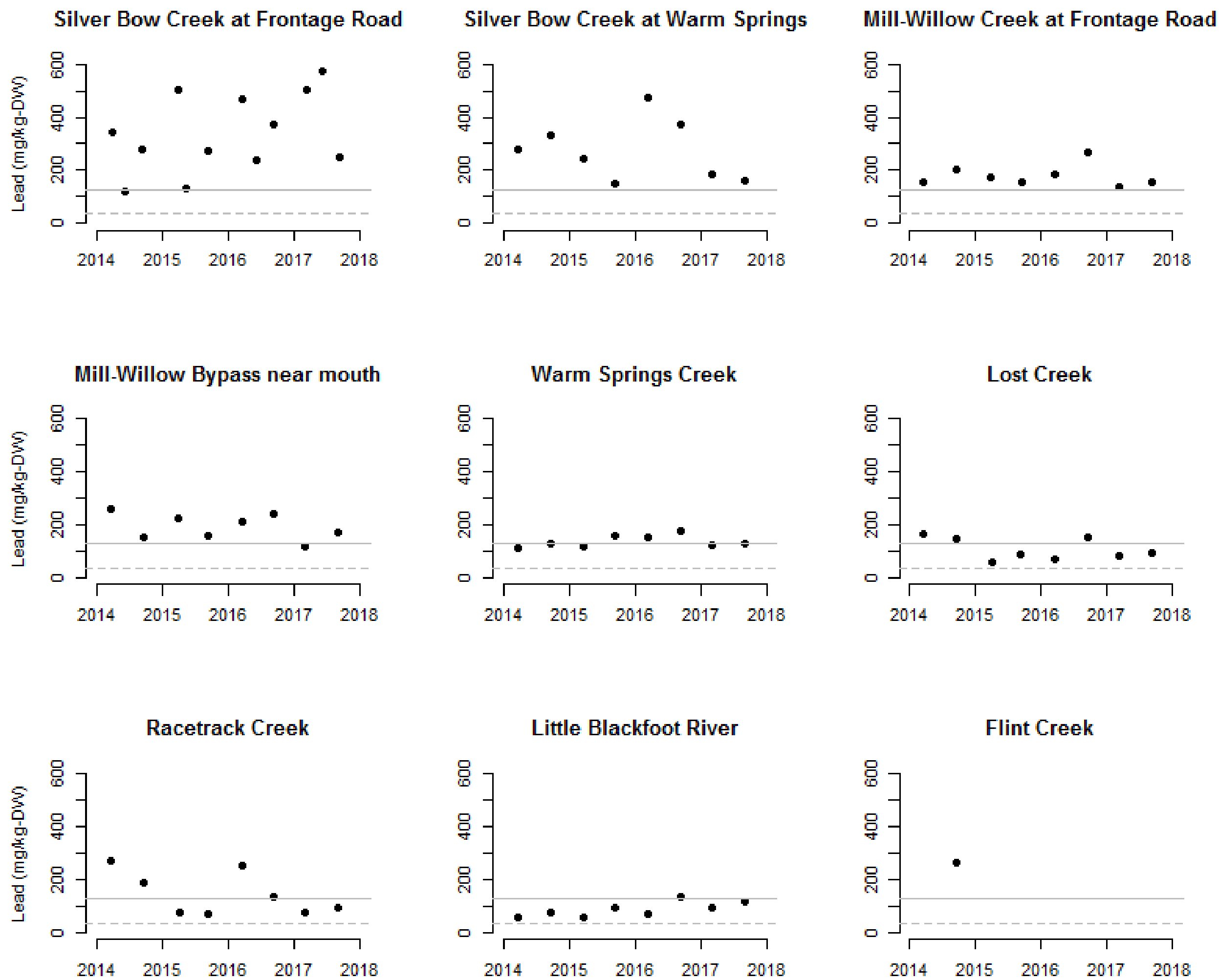

Figure 3-16. Time series of total lead concentrations (dry weight) in tributaries of the Clark Fork River, 2014-2017 Horizontal lines represent the "threshold effect concentration" (TEC; dashed line) at 35.8 mg/kg and the "probable effect concentration" (PEC; solid line) at 128 mg/kg [MacDonald et al., 2000].

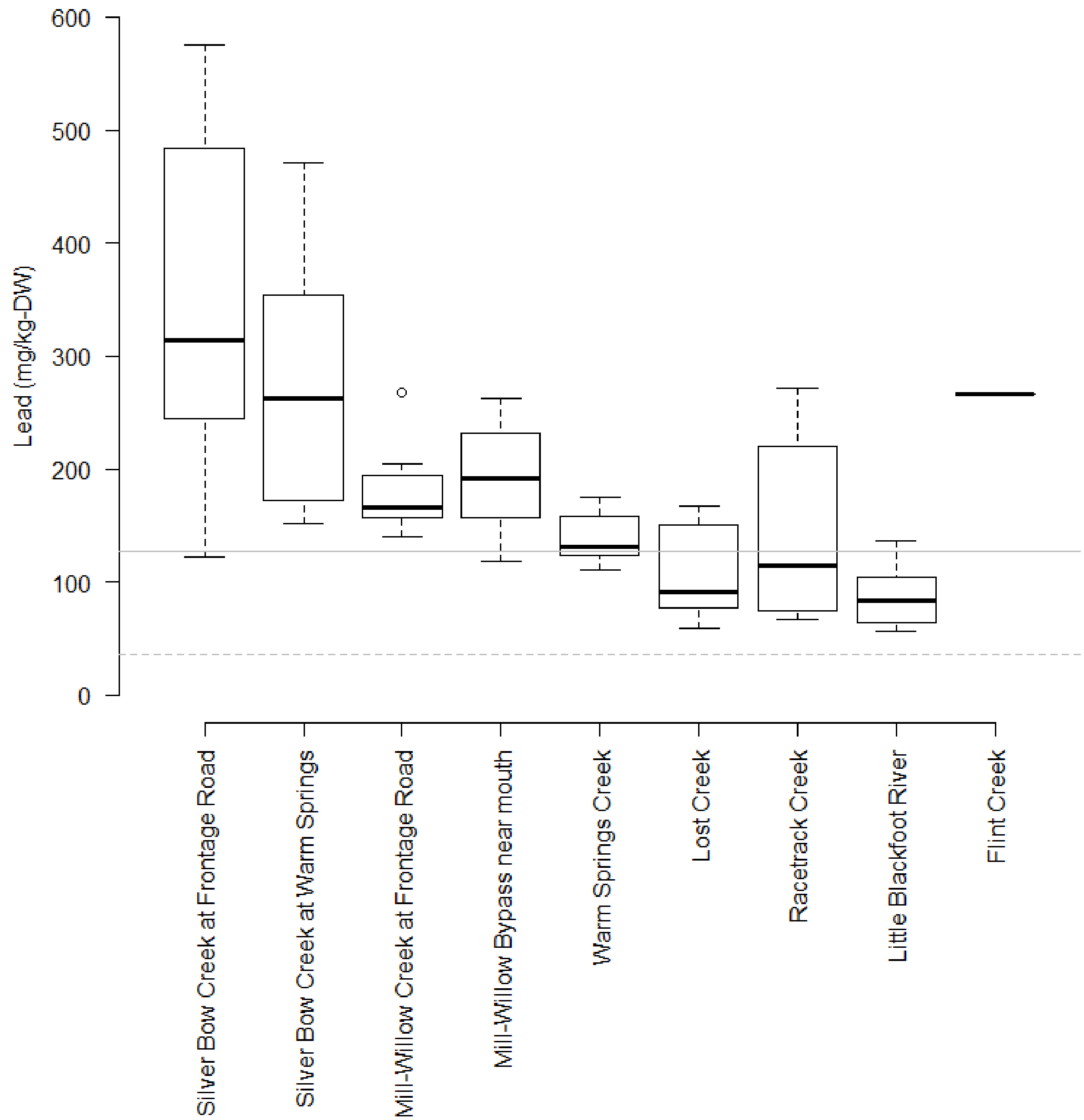

Figure 3-17. Boxplots of total lead concentration (dry weight) in Clark Fork River tributary monitoring sites, 2014-2017. Horizontal lines represent the "threshold effect concentration" (TEC; dashed line) at 35.8 mg/kg and the "probable effect concentration" (PEC; solid line) at 128 mg/kg [MacDonald et al., 2000].

3.3.2.5 Zinc

In the Clark Fork River mainstem, fine fraction (<0.065 mm) sediment zinc concentrations ranged from 859-1,990 mg/kg-DW in 2017 (Table 3-9). Exceedances of the TEC and PEC reference values occurred at all sites during both sample periods in 2017 (Table 3-9). Zinc concentrations at each site were similar in 2017 compared to prior monitoring years (Figure 3-18). Given the small number and variability of dry weight samples (i.e., ≤8) collected to date at these sites, we do not believe temporal trends can be seen at these sites yet. Longitudinally on the Clark Fork River mainstem, there is a slight declining trend in median sediment zinc concentrations between sites near Galen (river mile 0) and Turah (river mile 116) with the exception of the Williams-Tavenner Bridge site (river mile 34) where concentrations were elevated compared to upstream and downstream sites (Figure 3-19).

In the Clark Fork River tributaries, fine fraction (<0.065 mm) sediment zinc concentrations ranged from 116-1,190 mg/kg-DW in 2017 (Table 3-9). Exceedances of the zinc TEC occurred in all tributary sites in both sample periods of 2017, except for Racetrack Creek during Q3. PEC exceedances occurred in the Silver Bow Creek, Mill-Willow Creek, and Warm Springs Creek sites (Table 3-9). Zinc concentrations in most tributary sites were similar in 2017 to prior monitoring years, although in the Silver Bow Creek sites, zinc concentrations have been highly variable (Figure 3-20). Given the small number and variability of dry weight samples (i.e., ≤8), we do not believe temporal trends can be seen at these sites yet. Among paired tributary sites in Silver Bow Creek, median zinc concentrations for 2014-2017 were slightly lower at the downstream site (at Warm Springs) (Figure 3-21). Median zinc concentrations were about 30 percent higher in Mill-Willow Creek at the downstream site (near mouth) (Figure 3-21). In 2017, sediment zinc concentrations were 35-36 percent lower in Silver Bow Creek at the downstream site at Warm Springs, and 24-82 percent higher in Mill-Willow Creek at the downstream site. The lowest 2014-2017 median zinc concentrations occurred in Racetrack Creek and the Little Blackfoot River (Figure 3-21).

Table 3-9. Total zinc concentrations (mg/kg dry weight) in fine fraction (<0.065 mm) instream sediment samples from the Clark Fork River Operable Unit, 2017.

Site ID	Site Location	Sample concentration (mg/kg-WW)	
		Q1	Q3
Mainstem Sites			
CFR-03A	Clark Fork River near Galen	1510	1380
CFR-07D	Clark Fork River at Galen Road	1390	1860
CFR-11F	Clark Fork River at Gemback Road	1740	1310
CFR-27H	Clark Fork River at Deer Lodge	1260	1260
CFR-34	Clark Fork River at Williams-Tavenner Bridge	1990	1310
CFR-116A	Clark Fork River at Turah	919	859
Tributary Sites			
SS-19	Silver Bow Creek at Frontage Road	1490	1590
SS-25	Silver Bow Creek at Warm Springs	1190	1090
MCWC-MWB	Mill-Willow Creek at Frontage Road	689	511
MWB-SBC	Mill-Willow Bypass near mouth	682	808
WSC-SBC	Warm Springs Creek near mouth	469	528
LC-7.5	Lost Creek near mouth	385	325
RTC-1.5	Racetrack Creek near mouth	192	116
LBR-CFR-02	Little Blackfoot River at Beck Hill Road	171	262

(yellow)	Exceeds threshold effect concentration, 121 mg/kg [MacDonald et al., 2000].
(red)	Exceeds probable effect concentration, 459 mg/kg [MacDonald et al., 2000].

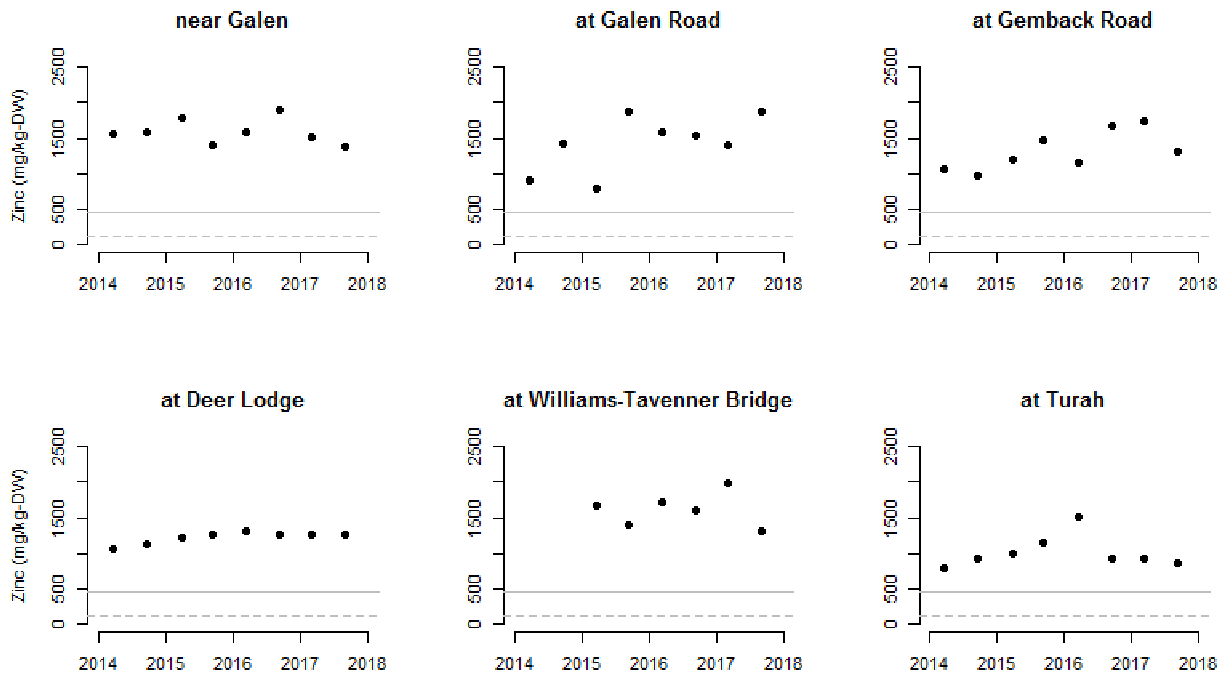

Figure 3-18. Time series of total zinc concentrations (dry weight) at each Clark Fork River mainstem monitoring site, 2014-2017. Horizontal lines represent the "threshold effect concentration" (TEC; dashed line) at 121 mg/kg and the "probable effect concentration" (PEC; solid line) at 459 mg/kg [MacDonald et al., 2000].

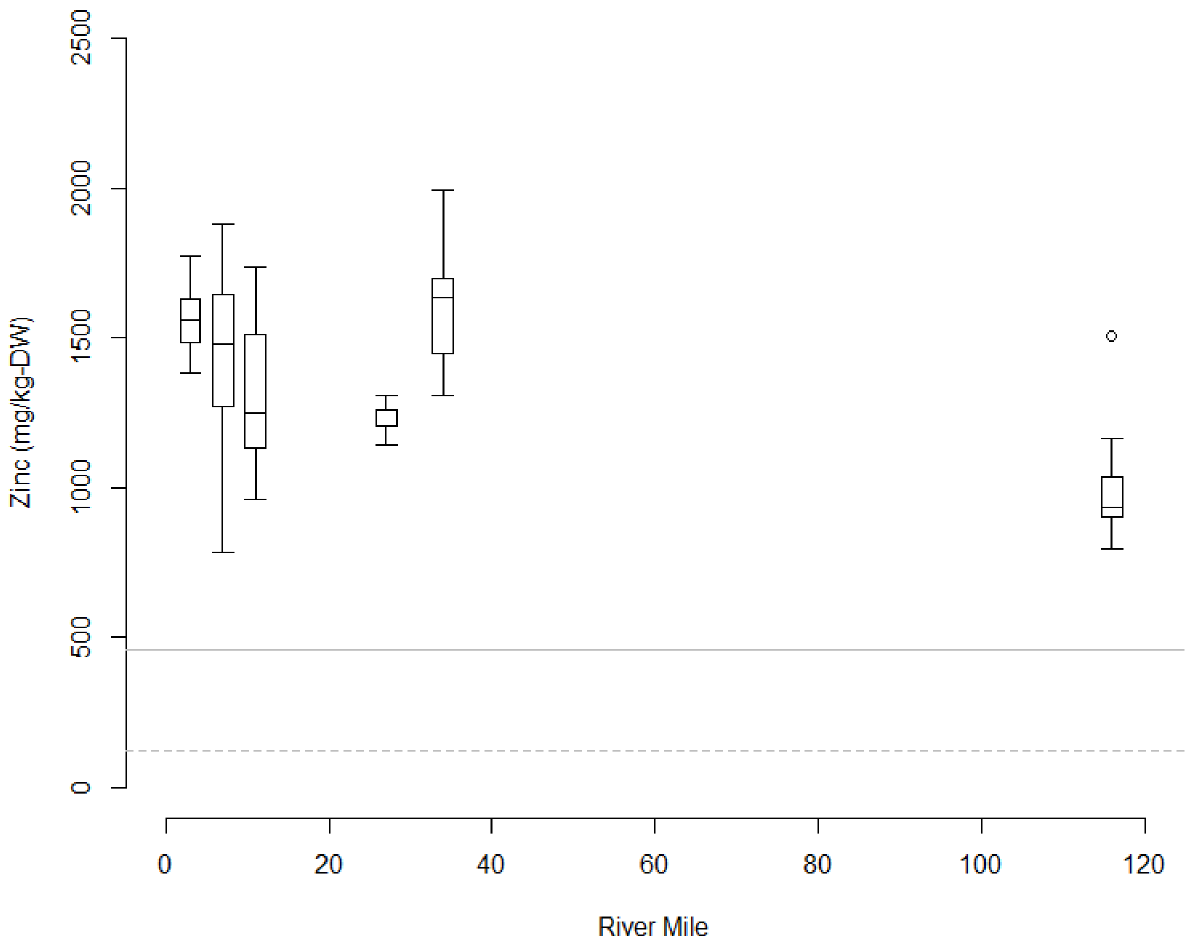

Figure 3-19. Boxplots of total zinc concentration (dry weight) at each Clark Fork River mainstem monitoring site, 2014-2017. River miles are measured downstream from the Silver Bow Creek-Warm Springs Creek confluence. Horizontal lines represent the "threshold effect concentration" (TEC; dashed line) at 121 mg/kg and the "probable effect concentration" (PEC; solid line) at 459 mg/kg [MacDonald et al., 2000].

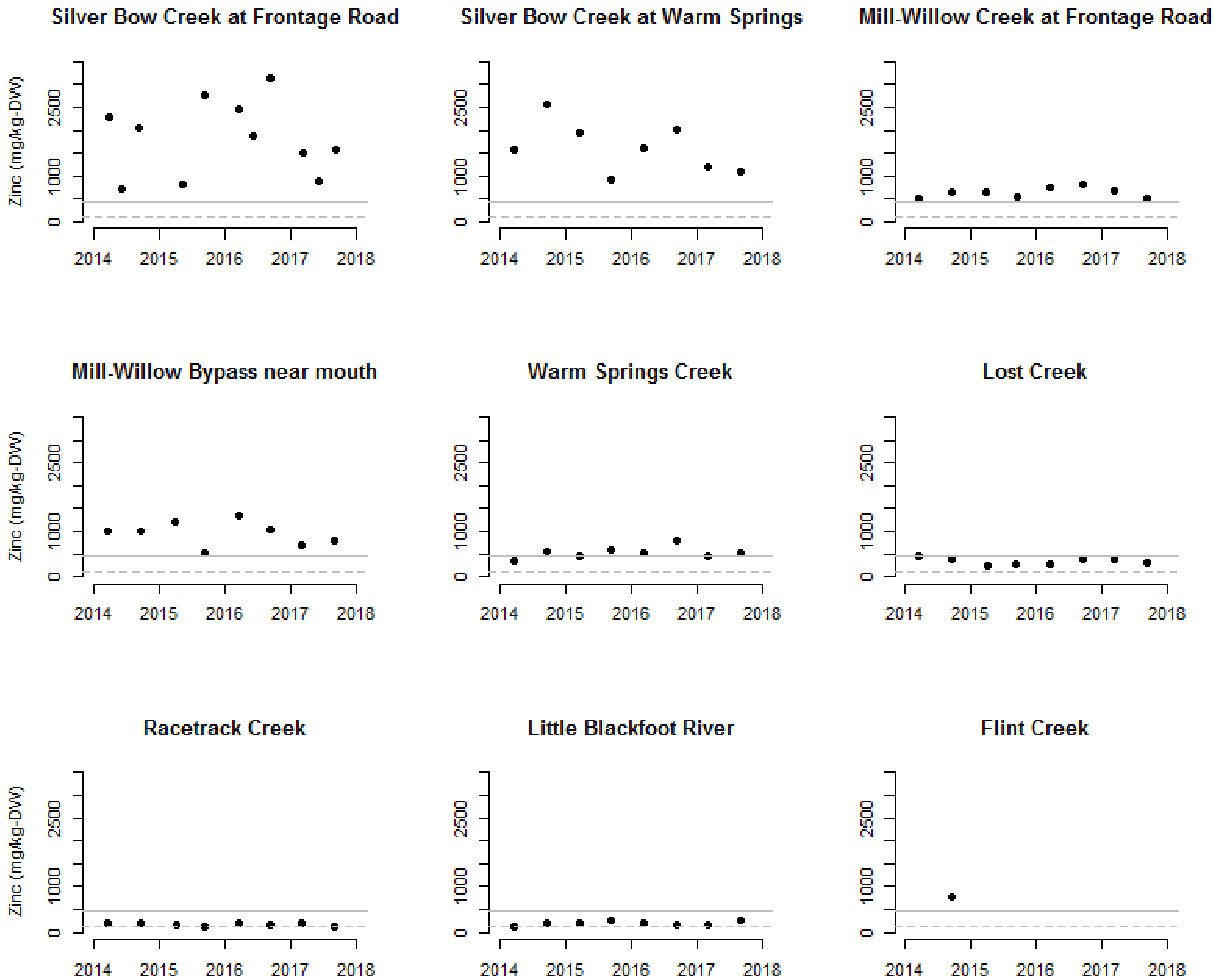

Figure 3-20. Time series of total zinc concentrations (dry weight) in tributaries of the Clark Fork River, 2014-2017[41]. Horizontal lines represent the "threshold effect concentration" (TEC; dashed line) at 121 mg/kg and the "probable effect concentration" (PEC; solid line) at 459 mg/kg [MacDonald et al., 2000].

[41] One sample from the Silver Bow Creek at Frontage Road site collected on March 26, 2015 had an unusually high zinc concentration (15,000 mg/kg-DW) and is not displayed.

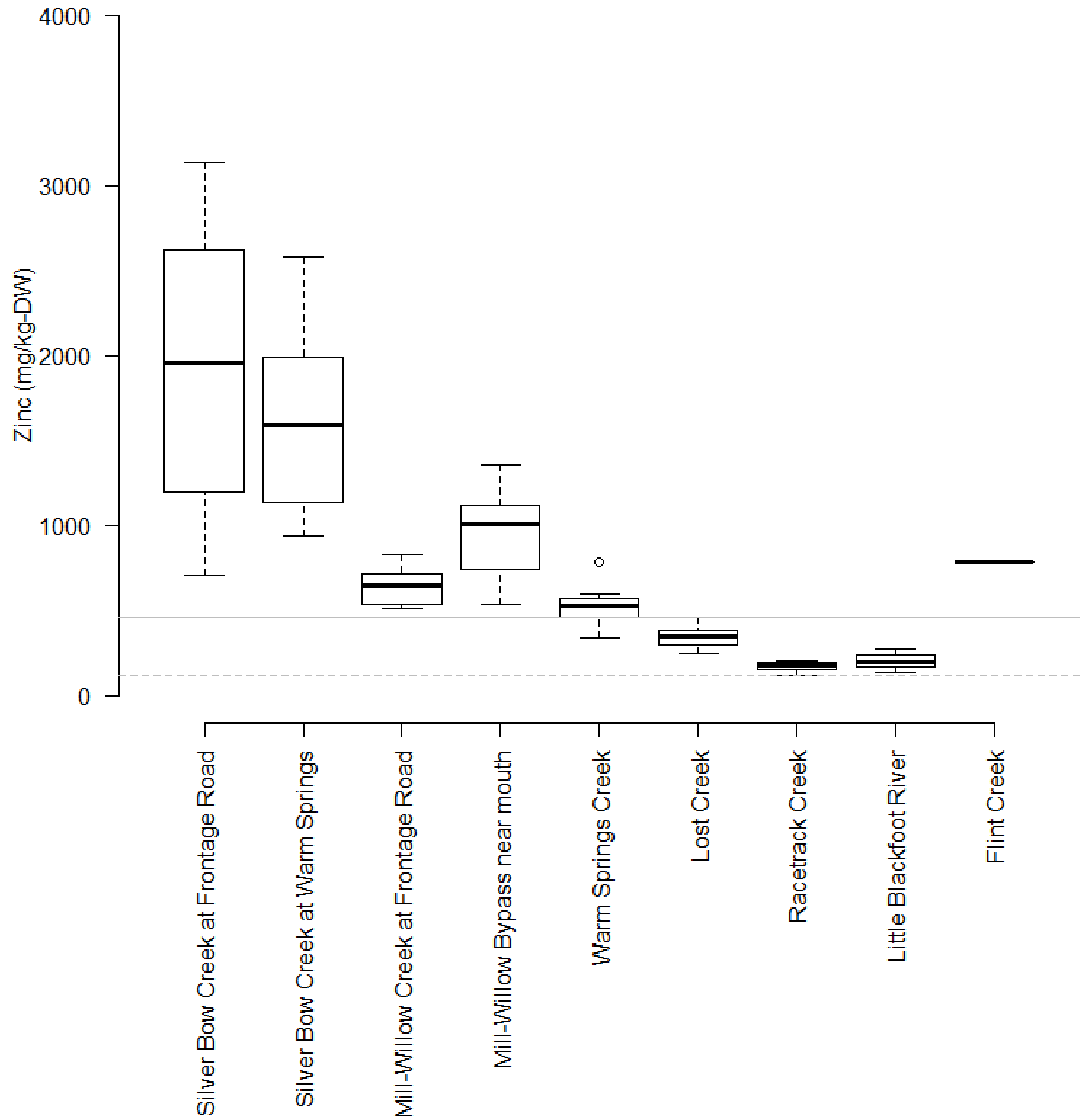

Figure 3-21. Boxplots of total zinc concentration (dry weight) in Clark Fork River tributary monitoring sites, 2014-2017[42]. Horizontal lines represent the "threshold effect concentration" (TEC; dashed line) at 121 mg/kg and the "probable effect concentration" (PEC; solid line) at 459 mg/kg [MacDonald et al., 2000].

[42] One sample from the Silver Bow Creek at Frontage Road site collected on March 26, 2015 had an unusually high cadmium concentration (15,000 mg/kg-DW) and is not displayed.

3.3.3 Data Validation

The quantitative portion of the data quality objectives (DQOs) for sampling precision consist of comparisons between field sample and field duplicate concentrations for each analyte in the monitoring program. In 2017, four field sample and field duplicate pairs were collected. In each pair, five comparisons were made, one for each metal in the fine fraction (<0.065 mm). In total, there were 20 analytes where field sample and duplicate relative percent difference (RPD) comparisons were made. Of those, 2 of 20 (10.0 percent) had an RPD greater than the DQO specified for sampling precision (40 percent). The range of RPD statistics among the 20 pairs was 1.0-51.8 percent (mean = 18.5 percent; SD = 14.9 percent).

3.4 DISCUSSION

3.4.1 Sample Size Fraction

Variability in sediment metals concentrations at any given monitoring site during any sampling event may be influenced by channel morphology and depositional processes. These factors may cause variability in the size composition of the sample, which in turn influences the concentrations of metals in the sample as size fraction is strongly related (inversely) to metal concentration in sediment samples in the CFROU. The proportion of sediment in the fine size fraction (<0.065 mm) was highly variable among sites and among sample periods. Sediment samples in the CFROU were analyzed in only the fine size fraction to minimize variability due to size fraction.

3.4.2 Contaminants of Concern

At each site, results of 2017 sediment sampling for dry weight sediment COC concentrations were generally consistent with previous dry weight results from 2014 through 2016. At this time, we do not believe temporal trends can be determined in COC concentrations with a reasonable level of confidence.

Exceedances of the more lenient reference value (the PEC) occurred in all 2017 CFROU mainstem and tributary samples for all COCs, except for zinc in Racetrack Creek during Q3. Exceedances of the more restrictive reference value (the TEC) were quite common for all COCs. Most mainstem sites exceeded the PEC for each COC during both sample periods. Exceptions include Turah (CFR-116A) and Deer Lodge (CFR-27H). Turah did not exceed the PEC for lead or cadmium in either sample period, and did not exceed the arsenic PEC during Q3. At Deer Lodge, the cadmium PEC was not exceeded during Q1. These non-exceedances mark an improvement over previous years when all mainstem sites exceeded PECs for each COC. In some tributaries, exceedances of the PEC were just as frequent as in the mainstem sites. All Silver Bow Creek and Mill-Willow Creek samples exceeded the TEC for each COC. Warm Springs Creek exceeded the PEC for each COC except lead and cadmium during Q1 and Q3, respectively. Exceedances of the

PECs were less common in Lost Creek and Racetrack Creek. The Little Blackfoot River did not exceed the PEC for any COC.

In the Clark Fork River mainstem since 2014, the highest cationic COC concentrations (cadmium, copper, lead, zinc) have tended to occur in the upper-most portion of Reach A (near Galen). Cationic COC concentrations have generally decreased with downstream distance from the near Galen site (CF3-03A), except for the Williams-Tavenner Bridge site (CFR-34). At CFR-34, cationic COC concentrations were slightly higher than expected given the prevailing spatial trend. However, sampling at CFR-34 did not begin until 2015 and therefore the sample size at CFR-34 is lower (6) than at the other mainstem sites (8). Arsenic concentrations in the mainstem also decreased with downstream distance from site CFR-03A but the decrease with distance was even more pronounced. As with the cationic COCs, arsenic concentrations at CFR-34 were a bit higher than expected given the overall upstream-to-downstream trend.

Based on the median sediment COC concentrations observed in the tributaries and mainstem since 2014, certain tributaries may be sources of sediment-associated COCs; specifically, arsenic in the Mill-Willow Bypass, cadmium, lead and zinc in Silver Bow Creek, and copper in Warm Springs Creek. Median sediment arsenic concentrations in the Mill-Willow Bypass near mouth (MWB-SBC), and median sediment cadmium, lead and zinc concentrations in Silver Bow Creek at Warm Springs (SS-25) were higher than at any mainstem sites. Additionally, arsenic concentrations in Silver Bow Creek at Warm Springs and cadmium concentrations in the Mill-Willow Bypass have been similar to concentrations in the mainstem sites immediately downstream which indicates that those tributaries also likely contribute a substantial amount of contamination to the mainstem.

In addition to loading from the tributaries, sediment arsenic concentrations increased substantially in Silver Bow Creek between sites above and below the Warm Springs Ponds and between sites in Mill-Willow Creek above and below the Mill-Willow Bypass (adjacent to the Warm Springs Ponds). These results may warrant further investigation to evaluate linkages between arsenic contamination in surface water in the ponds, groundwater, and instream sediment.

3.4.3 Data Validation

Ninety percent of the field sample and field duplicate pairs in 2017 had RPD statistics within 40 percent and therefore satisfied the project goal for "overall precision" for 100 percent of the data collected in 2017. A complete analysis of data validation procedures and results is described in Appendix A.

4.0 PERIPHYTON

4.1 INTRODUCTION

This chapter describes results of periphyton (benthic algae) monitoring within the Clark Fork River Operable Unit (CFROU) in 2017. Periphyton monitoring is one element of the Montana Department of Environmental Quality program for evaluating the influence of remediation on the ecology of the Clark Fork River.

Periphyton samples were analyzed for non-diatom (soft-bodied) algae, and diatom algae taxonomy and community structure. A suite of analytical metrics was applied to the diatom data to assess the degree of impairment from metals, nutrients, and sedimentation. These metrics included a stressor-specific tool developed for the Middle Rockies Ecoregion [Teply, 2010a; 2010b] and adopted by DEQ as a periphyton standard operating procedure for determining the probability of sediment impairment [DEQ, 2011]. In addition, a variety of diatom metrics developed for Montana mountain streams were used [Bahls et al., 1992; Bahls, 1993; Teply and Bahls, 2005] which are based on autecological preferences or requirements of freshwater diatoms [Lowe, 1974; Van Dam et al., 1994; Bahls, 2006].

Potential water quality or habitat stressors at each site, indicated by the taxonomic and functional composition of the algal flora, are described in a series of site-specific narratives.

4.2 METHODS

4.2.1 Sampling

Periphyton samples were collected by project staff from the 14 sites within the CFROU on August 30, 2017. Six sites were located on the Clark Fork River mainstem, and eight sites were located on tributary streams (Table 4-1). The sites sampled in 2017 were the same as those sampled in 2015 and 2016. Tributary sites were located on Silver Bow Creek, Mill and Willow Creeks (two sites), Warm Springs Creek, Lost Creek, Racetrack Creek, and the Little Blackfoot River. One composite periphyton sample was collected from multiple substrates and habitat types at each monitoring sites. Periphyton samples were collected following the DEQ PERI-1 method [DEQ, 2011]. Periphyton samples were preserved in the field with Lugols IKI solution and were transported to the laboratory on ice. Streamside Tailings Operable Unit (SSTOU) monitoring Site SS-19 (Silver Bow Creek at Frontage Road), located upstream of the Warm Springs Ponds system, was also sampled on August 30. Periphyton data from Site SS-19 are included in this report.

Table 4-1. Periphyton sampling locations in the Clark Fork River Operable Unit, 2017.

Site ID	Site Location	Co-located USGS Streamflow Gage	Location (GPS coordinates, NAD 83)	
			Latitude	Longitude
Tributary Sites				
SS-19	Silver Bow Creek at Frontage Road[1]	none	46.12247	-112.80032
SS-25	Silver Bow Creek at Warms Springs	12323750	46.18123	-112.77917
MCWC-MWB	Mill-Willow Creek at Frontage Road	none	46.12649	-112.79876
MWB-SBC	Mill-Willow Bypass near mouth	none	46.17839	-112.78270
WSC-SBC	Warms Springs Creek near mouth	12323770	46.18041	-112.78592
LC-7.5	Lost Creek at Frontage Road	12323850	46.21862	-112.77384
RTC-1.5	Racetrack Creek at Frontage Road	none	46.28395	-112.74921
LBR-CFR-02	Little Blackfoot River at Beck Hill Road	none	46.53710	-112.72443
Mainstem Sites				
CFR-03A	Clark Fork River near Galen	12323800	46.20877	-112.76740
CFR-07D	Clark Fork River at Galen Road	none	46.23725	-112.75302
CFR-11F	Clark Fork River at Gem Back Road	none	46.26520	-112.74430
CFR-27H	Clark Fork River at Deer Lodge	12324200	46.39796	-112.74283
CFR-34	Clark Fork at Williams-Tavenner Bridge	none	46..47119	-112.72492
CFR-116A	Clark Fork River at Turah	12334550	46.82646	-113.81424

4.2.2 Laboratory Analysis

4.2.2.1 Non-Diatom Algae

To prepare samples for analysis of soft-bodied algae, raw periphyton samples were vigorously shaken in the original sample container to homogenize the sample. The contents were then emptied into a porcelain evaporating dish. A small, random subsample of the liquid fraction containing suspended algal material (approximately 3-5 drops) was dispensed onto a welled glass microscope slide using a disposable plastic dropper. Visible (i.e., macroscopic) soft-bodied algae were teased apart and subsampled in proportion to their estimated importance relative to the total volume of algal material in the sample, and this material was added to the liquid fraction on the slide. The assembled subsample was then covered with a 22x30 mm cover slip, and the completed wet mount was analyzed for soft-bodied algae using an Olympus BHT compound microscope as described below.

The cover slip was scanned at 100X following a set pattern in the approximate shape of an hourglass (upper and lower horizontal transects linked by diagonal transects); magnification was increased to 200X or 400X as necessary to resolve detail in smaller specimens. All soft-bodied algae were identified to genus. The relative abundance of each soft-bodied algal genus (and of all diatom genera collectively) was estimated for comparative purposes, according to the following system:

- rare (r): represented by a single occurrence in the subsample;
- occasional (o): represented by multiple occurrences, but infrequently observed;
- common (c): represented by multiple occurrences, regularly observed;
- frequent (f): present in nearly every field of view;
- abundant (a): multiple occurrences in every field of view;
- dominant (d): multiple occurrences in every field of view in abundances beyond practical limits of enumeration.

Soft-bodied genera (and the diatom component) also were ranked numerically according to their estimated contribution to the total algal biovolume present in each sample.

4.2.2.2 Diatom Algae

To prepare samples for diatom analysis, organic matter was oxidized, and permanent fixed mounts of cleaned diatom material were prepared. Each raw periphyton sample was vigorously shaken in the original sample container to thoroughly homogenize the material, and a subsample of approximately 20 mL was poured into a 250 mL Pyrex beaker. Each beaker was treated with 30-50 mL of concentrated sulfuric acid, and a small quantity of five percent hydrogen peroxide and granulated potassium dichromate was added to each beaker. Samples were then covered with a Pyrex watch glass and gently heated to near-boiling for 1-2 hours to completely oxidize all organic matter in the sample. Samples were cooled, and then were topped off with deionized water. The diatom material settled for at least eight hours, and the clear supernatant decanted; this process was repeated at least five times to thoroughly flush all traces of oxidants from the diatom material.

Subsample volumes were adjusted to ensure manageable densities of diatom cells in suspension, and a small amount of each sample was dispersed onto clean 22-mm square glass cover slips. The cover slips were air dried, heated to 150 F, and affixed onto standard glass microscope slides with Naphrax mounting medium to create a permanent mount of diatom cells (frustules). To ensure a high-quality mount for diatom identification and to make replicates available for archiving, at least two slide mounts were made from each sample; one of the replicates was selected from each sample batch for analysis. An Olympus BHT compound microscope with a SPlan oil immersion objective (1000X total magnification) was used for diatom identifications and counts. A proportional count was performed along a vertical transect line across the exact center of the fixed cover slip. The starting point on the top edge was determined with the aid of the microscope's stage micrometer and recorded, and a total of 800 diatom valves (400 frustules) were identified and counted within a one-field-of-view width. Diatoms were identified to the lowest practical taxonomic level, generally to species.

4.2.3 Data Analysis

Results of periphyton taxonomic analyses are summarized by three general approaches: (1) taxa diversity, (2) diatom bioassessment indices, and (3) ecological interpretation of each site based on the results of the taxa diversity and bioassessment analyses.

4.2.3.1 Taxa Diversity

Diversity were summarized separately for non-diatom and diatom algae to provide a general understanding of the periphyton assemblages within each sample. Non-diatom diversity is summarized by taxonomic division for each site based on taxa identifications. Diatom species richness and Shannon diversity were compared in each sample to evaluate general trends among sites. General observations were made regarding commonly observed diatom genera.

4.2.3.2 Diatom Bioassessment Indices

Taxonomic results for diatom sample analysis were used to calculate an array of bioassessment indices within each sample. Three general types of bioassessment tools were applied to each: Increaser Taxa bioindices [DEQ, 2011; Teply, 2010a], Diatom Association Metrics for Montana Mountain Streams [Bahls, 1993], and Ecological Indicator Values of Freshwater Diatoms [Van Dam et al., 1994]. Each bioassessment index generates a value summarizing the degree of impairment to the diatom assemblage at each site. Some indices are designed to represent impairment from specific environmental stressors (e.g., inorganic nitrogen enrichment) whereas others represent general impairment.

When possible, stressor-specific bioindex scores were compared to measured water quality results to evaluate the efficacy of each index as predictors of water. For example, if a bioindex was intended to assess impairment specifically from inorganic nitrogen, the bioindex scores were compared to paired inorganic nitrogen (i.e., ammonia, nitrate and nitrite) concentrations measured at the same sites. Comparisons were made by fitting simple linear regressions (SLR) between the stressor-specific bioindex score (dependent variable) to the concentrations of a selected water quality parameter representing the stressor of interest (independent variable). SLRs with probability values (*p*-values) less than 0.05 were considered statistically significant. Independent variables that represented each stressor of interest could be selected from a variety of water quality parameters. Parameters were chosen as independent variables that were believed to be likely correlated with each stressor-specific biometric. We did not know if the immediate conditions or the general conditions would structure the diatom community. Therefore, we fit all regressions of stressor-specific bioindex scores to the immediate (Q3) water quality conditions[43] and, separately, to the 2017 annual average conditions[44]. No surface water

[43] Water quality samples were collected (see Chapter 1.0) about one week after periphyton samples were collected.

[44] From quarterly sampling with two additional spring runoff samples.

chemistry measurements were made in Lost Creek or Racetrack Creek and therefore results from those sites were not included in the regression models.

4.2.3.2.1 Increaser Taxa

Each periphyton sample was evaluated according to DEQ's current periphyton standard operating procedure [DEQ, 2011] using "pollutant-diagnosing biometrics based on stressor-specific increaser diatom taxa as described in Teply [2010a; 2010b]". The pollutant-diagnosing biometrics described in DEQ [2011] are known as "increaser taxa" and are specifically designed to diagnose stress from sediments and nutrients. According to DEQ [2011], "the assessment tools have been designed to function properly in the presence (or absence) of the other stressor types". Teply [2010a] also provides guidance for a metal increaser taxon biometric to diagnose stress from metal contamination although that metal-specific biometric was not adopted by DEQ [2011]. Each increaser taxa biometric provides an estimate of the probability of impairment for each specific stressor of interest and those impairment probabilities are summarized in this report.

Increaser taxa results were evaluated by correlating the impairment probabilities for each particular stressor with annual average and Q3 concentrations of each stressor. To evaluate the sediment increaser taxa bioindex, sediment impairment probabilities were regressed on annual average total suspended sediment concentrations. To evaluate the metals increaser taxa bioindex, metals impairment probabilities were regressed on the sum total concentration[45] of the primary CFROU contaminants of concern[46] (arsenic, cadmium, copper, lead, and zinc). To evaluate the nutrient increaser taxa bioindex, nutrient impairment probabilities were regressed on total nitrogen concentrations and, separately, on total phosphorus concentrations. Separate models fit to total nitrogen and total phosphorus concentrations were developed because the correlation would presumably be highly dependent on whether the system was nitrogen- or phosphorus-limited. If the system was phosphorus-limited, we would expect that a regression of nutrient impairment probability on total nitrogen concentrations would find no relationship but that a significant relationship with phosphorus concentrations would be found.

4.2.3.2.2 Diatom Association Metrics for Montana Mountain Streams

In addition to the increaser taxa bioindices, we have selected seven diatom association metrics to provide additional assessments of environmental quality at these sites (Table 4-2) as well as an evaluation of overall biointegrity at each site. Results of these metrics from each site were tabulated and sites with impaired conditions were highlighted. Each of these seven diatom association metrics provides a general measure of environmental impairment to the diatom assemblage and therefore none were correlated in relation to any specific water quality conditions

[45] Total recoverable concentrations.

[46] Excluding mercury.

using the regression approaches described in Section 6.2.3.2. The following paragraphs summarize each metric.

Species richness is a common measure of environmental impairment with greater diversity generally reflecting more heterogeneous environmental conditions and low diversity generally reflects environmental homogeneity potentially due to impairment from a specific stressor such as metal contamination. Bahls [1979] utilized species richness as a measure of diatom biointegrity.

The diversity index is based on the Shannon diversity index which includes measures of species evenness and species richness and is sensitive to variation in water quality [Bahls, 1993].

The pollution index [Bahls, 1993] synthesizes the three pollution tolerance groups defined by Lange-Bertalot [1979] with diatom autecological profiles described by Lowe [1974] and unpublished Montana diatom data described in Bahls [2006]. Diatom species are assigned on an ordinal scale from 1-3 with a score of 1 corresponding to “most-tolerant”, 2 corresponding to “less-tolerant”, and 3 corresponding to “sensitive” for tolerance to nutrient enrichment, mineral salts, elevated temperatures, or metal toxicity.

Many diatom species are motile (i.e., capable of locomotion). The siltation index [Bahls, 1993] is calculated as the total percent abundance of motile diatom taxa which include species belonging to the genera *Navicula, Nitzschia, Surirella* and other closely related taxa. Motility may be an adaptation to siltation, as a mechanism that allows individual diatom cells to avoid inundation by deposited sediment.

The disturbance index [Barbour et al., 1999] considers the percent relative abundance of the diatom *Achnanthidium minutissimum*, which is highly specialized in the post-disturbance recolonization of stream substrates. Elevated numbers may be indicative of recent environmental stress caused by elevated or highly variable stream flows, water velocities, and water temperatures at a site.

In addition to the metrics described (Table 4-2), an overall biointegrity rating was assigned for each SSTOU monitoring site. This rating essentially provides a summary of the seven metrics from Table 4-2 and is determined in a series of steps. First, at each site, scores were assigned for each diatom association metric (Table 4-2) on an ordinal scale: “excellent” = 3, “good” = 2, “fair” = 1, and “poor” = 0. Second, the mean score of those seven metrics at each site was calculated. The mean score of the seven metrics was then used as the overall biointegrity rating on another ordinal scale: “excellent” more than 2.7, “good” = 1.7-2.7, “fair” = 0.7-1.7, and “poor” less than 0.7.

Table 4-2. Summary of diatom association metrics to evaluate biological integrity in mountain streams: references range of values, expected response to increasing impairment or stress, and criteria for rating levels of biological integrity.

Metric	Biological Integrity				Range	Expected Response	Reference
	Excellent	Good	Fair	Poor			
	Impairment or Stress						
	None	Minor	Moderate	Severe			
	Use Support						
	Full	Full	Partial	None			
Species Richness[47]	>29	20-29	19-10	<10	0-100+	decrease[48]	Bahls, 1979
Diversity Index[49]	>2.99	2.00-2.99	1.00-1.99	<1.00	0-5+	decrease[50]	Bahls, 1993
Pollution Index[51]	>2.50	2.01-2.50	1.50-2.00	<1.5	1-3	decrease	Bahls, 1993
Siltation Index[52]	<20.0	20.0-39.9	40.0-59.9	>59.9	0-90+	increase	Bahls, 1993
Disturbance Index[53]	<25.0	25.0-49.9	50.0-74.9	>74.9	0-100	increase	Barbour et al., 1999
Dominant Species (percent)[54]	<25.0	25.0-49.9	50.0-74.9	>74.9	~5-100	increase	Barbour et al., 1999
Abnormal Valves (percent)[55]	0	>0.0, <3.0	3.0-9.9	>9.9	0-30+	increase	McFarland et al., 1997

[47] Based on a proportional count of 400 cells (800 valves).

[48] May increase somewhat in mountain streams in response to slight to moderate increases in nutrients or sediment

[49] Base 2 [bits].

[50] May increase somewhat in mountain streams in response to slight to moderate increases in nutrients or sediment

[51] Composite numeric expression of the pollution tolerances assigned by Lange-Bertalot [1979] to the common diatom species.

[52] Sum of the percent abundances of all species in the genera Navicula, Nitzschia and Surirella.

[53] Percent abundance of *Achnanthidium minutissimum* (synonym: *Achnanthes minutissima*).

[54] Percent abundance of the species with the largest number of valves in the proportional count.

[55] Valves with an irregular outline, with abnormal ornamentation, or both.

4.2.3.2.3 Freshwater Diatoms as Ecological Indicators

Van Dam et al. [1994] identified diatom taxa considered to be indicators of specific conditions. Conditions identified specifically by the Van Dam et al. [1994] indicator taxa included inorganic nutrient tolerance, organic nitrogen tolerance, and hypoxia tolerance.

Van Dam et al. [1994] classified diatom species as tolerant, indifferent, and intolerant of inorganic nitrogen (primarily ammonia, nitrate, and nitrite) and phosphorus enrichment. The relative abundance of those groups of species was summarized for each sample. Comparisons among sites presumed that the relative abundance of tolerant species would increase in relation to inorganic nutrient concentrations and the relative abundance of intolerant species would decrease in relation to inorganic nutrient concentrations. The efficacy of this bioindex as applied to the CFROU was evaluated by correlating the relative abundance of inorganic nutrient-tolerant species with inorganic nitrogen (i.e., total ammonia combined with nitrate and nitrite) concentrations using simple linear regressions. Four separate regressions were fit for tolerant and intolerant species (each as a separate dependent variable) and for annual average and Q3 (each as a separate independent variable) inorganic nutrient concentrations. The relationship between these dependent variables was not fit to inorganic phosphorus concentrations because inorganic (i.e., phosphate) concentrations were not measured in this monitoring program and could not be deduced from other measured parameters (see Chapter 1.0).

Most diatoms are nitrogen-autotrophs and are unable to directly utilize organic nitrogen. For some nitrogen-autotrophs, organic nitrogen may be toxic. Some diatoms directly assimilate organic nitrogen in addition to, or as an alternative to, inorganic nitrogen (i.e., facultative nitrogen heterotrophs). Van Dam et al. [1994] classified diatom species by trophic state, either as nitrogen-autotrophs or nitrogen heterotrophs. Nitrogen-autotrophs were further classified as tolerant or intolerant of enriched organic nitrogen. Relative abundances of diatoms in each group were quantified for each site. Nitrogen-heterotroph relative abundance is expected to generally increase in relation to organic nitrogen concentrations and the opposite relationship is expected for nitrogen-autotrophs intolerant of organic nitrogen. The efficacy of the trophic state bioindex results were evaluated by correlating the relative abundance of the nitrogen-heterotroph and nitrogen-autotroph and intolerant groups to annual average and Q3 organic nitrogen[56] concentrations using simple linear regressions.

Van Dam et al. [1994] observed that some diatoms are intolerant of saprobic conditions (i.e., polluted by organic materials in various states of decomposition resulting in high biochemical oxygen demand and low (less than 75 percent) dissolved oxygen saturation. Diatoms with such sensitivities are referred to as oligosaprobous or β-mesosaprobous and would likely be found in low relative abundance in water with excessive organic pollution. Similarly, water with low dissolved oxygen saturation would likely have few species sensitive to hypoxia. The relative

[56] Organic nitrogen concentrations were not measured directly but were derived by the difference between measured total nitrogen concentrations and the sum of the inorganic nitrogen (ammonia, nitrate, and nitrite) concentrations (see Chapter 1.0 for results of surface water sampling).

abundance oligosaprobous or ß-mesosaprobous diatoms and oxygen-sensitive diatoms were summarized by site. No attempt was made to relate these indices to water chemistry because hypoxic conditions would likely only be identifiable during night sampling [Gammons et al., 2011] and all water quality sampling in this system was conducted during the daytime.

4.2.3.3 Ecological Interpretations

Narrative interpretations presented below infer the degree and potential causes of water quality impairment for each site. These interpretations are based on a summary of taxa diversity and bioassessment results from each site.

4.3 RESULTS

4.3.1 Taxa Diversity

4.3.1.1 Non-Diatoms

A total of 32 genera of non-diatom algae representing four divisions were identified in the CFROU in 2017. Divisions observed included Xanthophyta (yellow-green algae), Rhodophyta (red algae), Cyanophyta (blue-green algae), and Chlorophyta (green algae).

Diversity of all non-diatom algae genera ranged from 7 to 17 among mainstem sites (Figure 4-1) and from 8 to 19 among tributary sites (Figure 4-2). Mainstem diversity was highest in the downstream-most site at Turah (CFR-116A) and lowest in the upstream-most sites (CFR-03A and CFR-07D) (Figure 4-1). In the tributary sites, diversity was highest in the Little Blackfoot River (Figure 4-2).

Green algae were the most diverse division at all sites followed by blue-green algae (at most sites) (Figure 4-1; Figure 4-2). Yellow-green algae were present at one mainstem site and two tributary sites and red algae were present at two mainstem sites and five tributary sites (Figure 4-1; Figure 4-2).

A total of seventeen genera of green algae were identified in the 2017 CFROU samples, including: the macroscopic filamentous genus *Chara*; the microscopic filamentous genera *Cladophora, Microspora, Mougeotia, Oedogonium, Stigeoclonium,* and *Ulothrix;* the colonial genera *Coelastrum, Oocystis*, *Pediastrum*, *Scenedesmus, Sphaerocystis and Tetraspora;* the single-celled genus *Ankistrodesmus*; and the single-celled desmid genera *Closterium, Cosmarium* and *Staurastrum*. These genera are generally indicative of cool, moderately nutrient-rich water. Many of these species are tolerant of elevated nutrients, acidity, metals, or combinations of those conditions. *Cladophora* was an important taxon at all mainstem Clark Fork sites and at six tributary sites. *Oedogonium* was common at five tributary sites and at one mainstem site. *Cladophora* forms large masses, often 30 centimeters or more in length, composed of numerous branched filaments that provide extensive surface habitat for attached diatoms and other microalgae. *Oedogonium* occurs as macroscopic masses of unbranched filaments that are frequently colonized by microalgae. Both *Cladophora* and *Oedogonium* prefer cool, flowing, alkaline water and are tolerant of nutrient enrichment.

From one to six genera of blue-green algae were present at each site in 2017. Blue-green algae genera observed included: *Chamaesiphon, Dichothrix, Heteroleibleinia*, *Nostoc* and *Tolypothrix*. *Nostoc* was particularly common and is resistant to scour and desiccation as it forms masses of trichomes (i.e. filaments composed of individual cells) encased in a tough, colonial mucilage. *Nostoc* possesses specialized cells called heterocytes for fixation of atmospheric nitrogen through enzyme reactions. *Nostoc* therefore has a competitive advantage over other non-diatom algae in water with low inorganic nitrogen concentrations. *Phormidium* is a cosmopolitan blue-green alga that occurs within a relatively broad range of habitats and water quality conditions and can form extensive macroscopic growths. *Phormidium* was common in the mainstem, particularly at Deer Lodge (CFR-27H) and in Mill-Willow Bypass near mouth (MWB-SBC). *Tolypothrix* is a filamentous blue-green alga that often occurs in relatively unpolluted water attached to stones, macrophytes or other algae, sometimes forming mats. *Tolypothrix* is also a nitrogen fixer. *Tolypothrix* was common in some tributary sites, specifically both Mill-Willow Creek sites (MCWC-MWB and MWB-SBC) and the Little Blackfoot River (LBR-CFR-02). It was also common in the Clark Fork River at Galen Road (CFR-07D) and at Gemback Road (CFR-11F). *Chamaesiphon* and *Heteroleibleinia* are microscopic blue-green algae that commonly occur as epiphytes (i.e., plants that grow on other plants) on, or entangled amongst, larger filamentous green algae (e.g., *Cladophora* or *Oedogonium*). *Chamaesiphon* often occurs in high densities that cover much of the surface of the host alga, but due to its extremely small size, rarely contributes significant biovolume relative to most other algal taxa. *Chamaesiphon* often is found on submerged substrates in cold water in mountain streams, and generally prefers low to moderate levels of nutrients and dissolved solids.

The filamentous alga *Audouinella,* a red alga, is a cosmopolitan form that prefers circumneutral (i.e., with a pH of about 7) to slightly alkaline water that is moderately low in nutrients and dissolved solids. *Audouinella* was common in Mill-Willow Creek at Frontage Road (MCWC-MWB), Warm springs Creek near mouth (WSC-SBC), Lost Creek (LC-7.5), and Racetrack Creek (RTC-1.5).

Yellow-green algae genera, including filamentous forms *Tribonema* and *Vaucheria,* were generally scarce in 2017. *Vaucheria* was ranked within the top six most common taxa at Springs Creek (WSC-SBC) and in the Little Blackfoot River (LBR-CFR-02). Often these taxa occur water high in concentrations of dissolved humic substances (e.g., tannins) associated with decaying vegetation and bog environments.

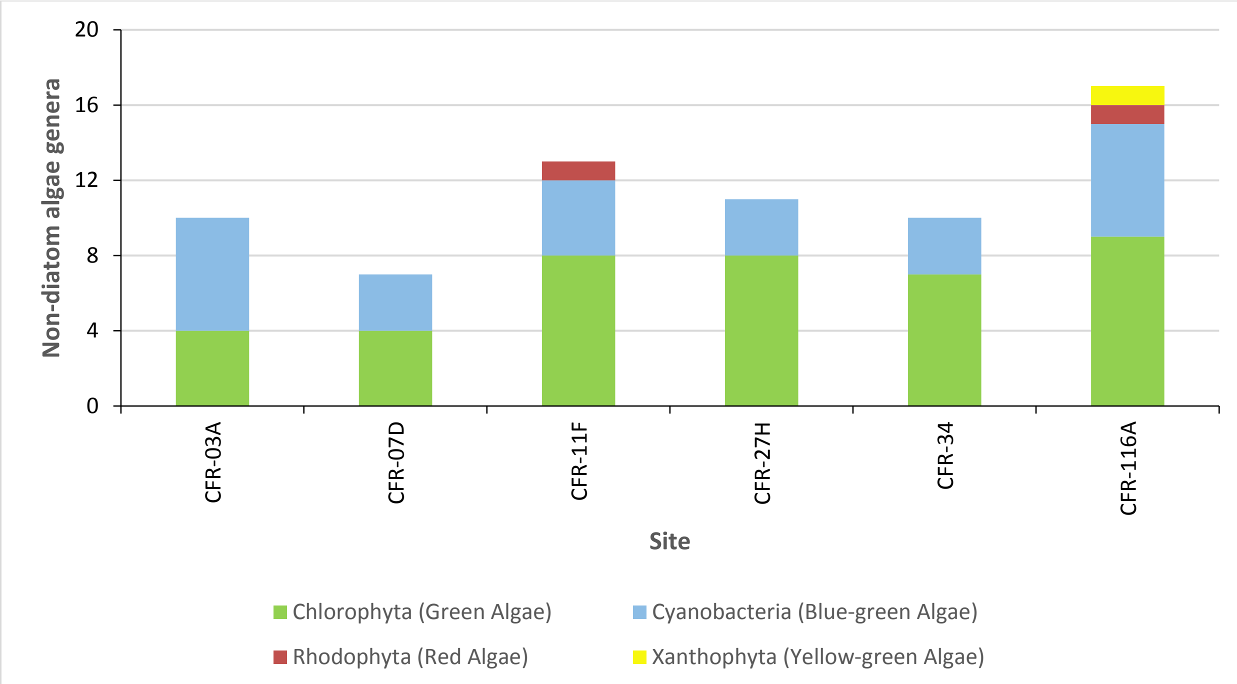

Figure 4-1. Diversity of non-diatom algae genera in mainstem sites of the Clark Fork River Operable Unit, 2017.

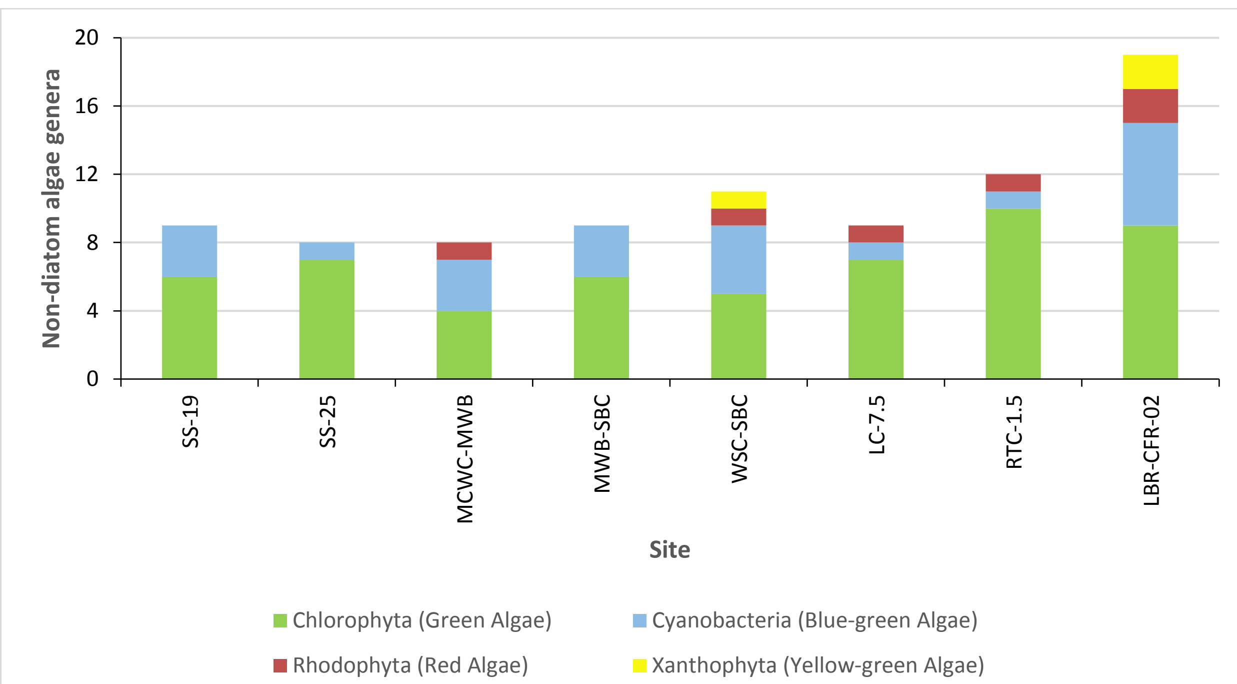

Figure 4-2. Diversity of non-diatom algae genera in tributaries of the Clark Fork River Operable Unit, 2017.

4.3.1.2 Diatoms

A total of 176 diatom species, including varieties and subspecies, were identified in the 2017 CFROU periphyton samples.

Diatom species richness and Shannon Diversity were fairly consistent among sites in the CFROU, particularly in the mainstem (Figure 4-3; Figure 4-4).

Average species richness was similar in the mainstem and in the tributaries but among sites, species richness was more variable in the tributaries. Mean species richness was 57 (standard deviation [SD] = 5) in the mainstem and 58 (SD = 10) in the tributaries. Sites with relatively high species richness (i.e., more than one SD above the mean) included Lost Creek (LC-7.5; 1.7 SD above the tributary mean) and Clark Fork River at Deer Lodge (CFR-27H; 1.5 SD above the mainstem mean). Sites with relatively low species richness included only Racetrack Creek (RTC-1.5; 1.5 SD below the tributary mean).

Mainstem sites had higher average and lower variability in Shannon Diversity compared to the tributary sites. Mean Shannon Diversity was 3.05 (SD = 0.16) in the mainstem and 2.94 (SD = 0.39) in the tributaries. Two sites with relatively high species richness also had high Shannon Diversity including Lost Creek (1.2 SD above tributary mean) and the Clark Fork River at Deer Lodge (1.6 SD above mainstem mean). Similarly, Racetrack Creek had low species richness and also had low Shannon Diversity (1.9 SD below tributary mean). One mainstem site (CFR-07D) had low Shannon Diversity (1.5 SD below mainstem mean) and also had relatively low species richness (1.0 SD below mainstem mean).

Diatom algae were dominant components of the periphyton assemblage at all CFROU sites in 2017. Diatoms were ranked first in estimated biovolume relative to non-diatom algae at three of six Clark Fork River mainstem sites and at six of seven tributary sites monitored in 2017. Diatoms were ranked second in estimated biovolume at mainstem Sites CFR-03A (Clark Fork River near Galen) and CFR-27H (Clark Fork River at Deer Lodge), and third in estimated biovolume at Site CFR-34 (Clark Fork River at Williams-Tavenner Bridge) and tributary Site LBR-CFR-02 (Little Blackfoot River at Beck Hill Road.

Diatom genera with relative abundance values of 5 percent or greater at one or more CFROU sites included: *Achnanthidium*, *Amphora*, *Cocconeis, Cymbella, Diatoma, Ellerbeckia, Encyonema*, *Encyonopsis, Epithemia, Fragilaria*, *Gomphonema*, *Navicula, Nitrschia*, *Staurosira*, and *Stephanocyclus*.

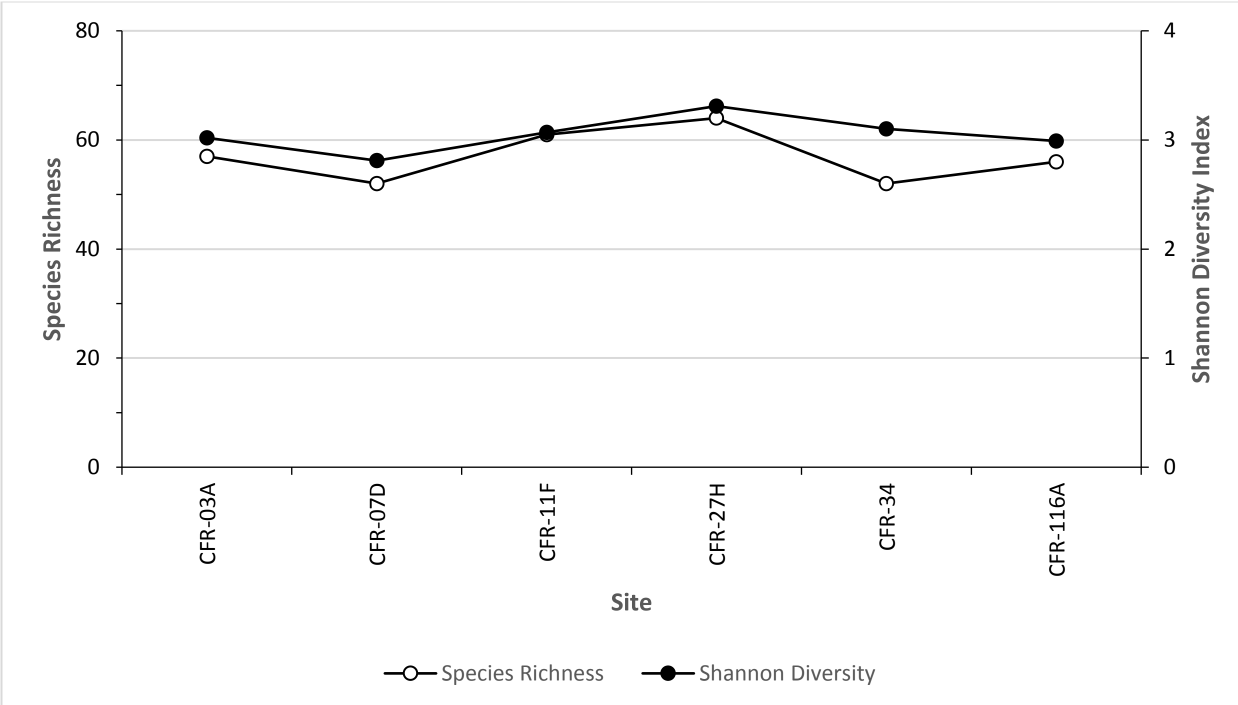

Figure 4-3. Diatom species richness and Shannon Diversity values in mainstem sites of the Clark Fork River Operable Unit, 2017.

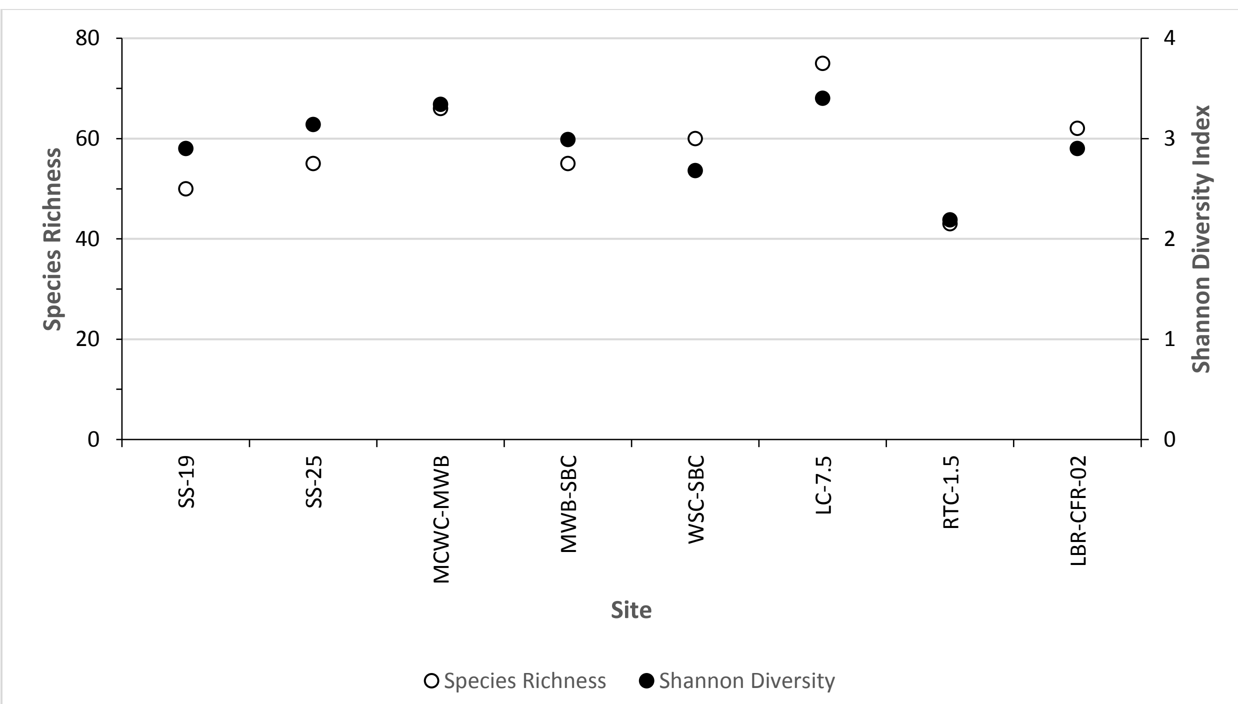

Figure 4-4. Diatom species richness and Shannon Diversity values in tributaries of the Clark Fork River Operable Unit, 2017.

4.3.2 Diatom Bioassessment Indices

4.3.2.1 Increaser Taxa

4.3.2.1.1 Sediment

Based on the relative abundance of diatom species considered sediment increaser taxa, the probability of impairment from sediments in the CFROU mainstem sites ranged from 25 percent at Deer Lodge (CFR-27H) to 90 percent near Galen (CFR-03A) and at Galen Road (CFR-07D) (Figure 4-5). Generally, sediment impairment probability declined at each downstream site in the mainstem with the exceptions of CF-07D and CFR-34 (Figure 4-5). In the tributaries, impairment probabilities were highly variable. Impairment probabilities in the Silver Bow Creek and Mill-Willow Creek sites was relatively high (55-90 percent); low (not more than 30 percent) in Warm Springs Creek, Lost Creek, and Racetrack Creek; and high (95 percent) in the Little Blackfoot River (Figure 4-6).

There was a statistically significant relationship between sediment impairment probability and Q3 total suspended sediment concentrations (p-value from SLR = 0.0141; r^2 = 0.4685) but the relationship was not as expected. Based on the model fit, sediment impairment probabilities actually declined by 12 percent for every 1 mg/L increase in Q3 total suspended sediment concentration. There is no reason to believe that increased suspended sediment concentrations in Q3 would result in decreased impairment from sediment. The unexpected result may be because total suspended sediment concentrations in Q3 were low (not more than 5 mg/L) and at those low concentrations there was actually no relationship between these variables and the test provided a spurious result, or a Type I Error (i.e., a “false positive”). The result of the regression of sediment impairment probabilities on average annual total suspended sediment concentrations found no relationship (p-value from SLR = 0.0756).

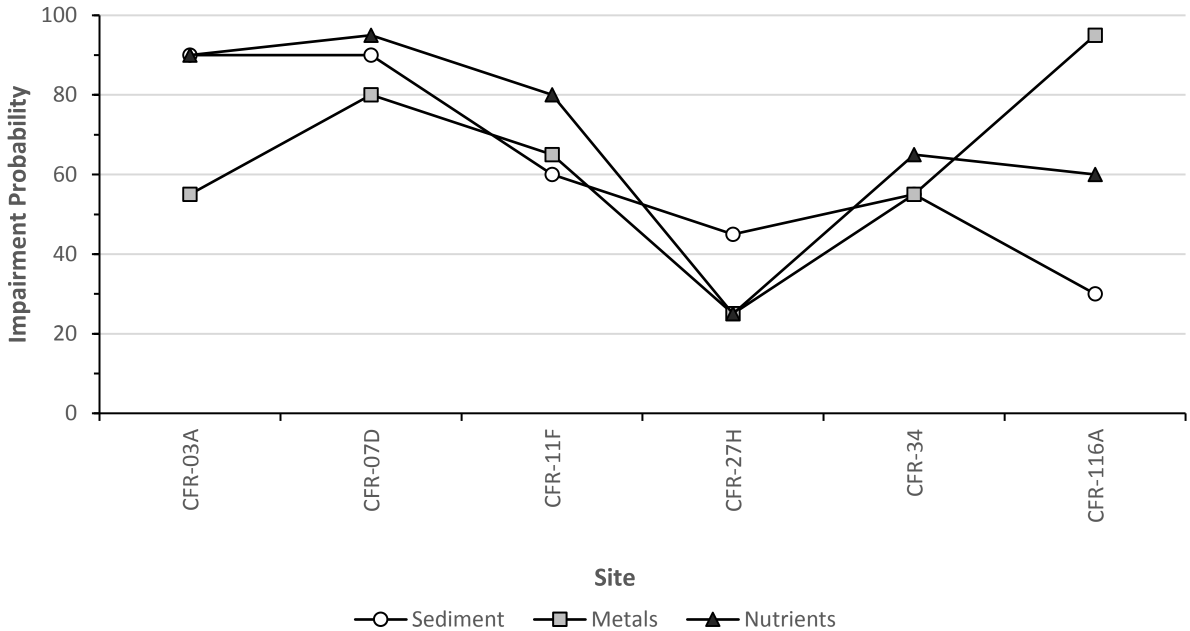

Figure 4-5. Impairment probabilities from specific environmental stressors at each mainstem site in the Clark Fork River Operable Unit in 2017 based on relative abundances of stressor-specific diatom increaser taxa.

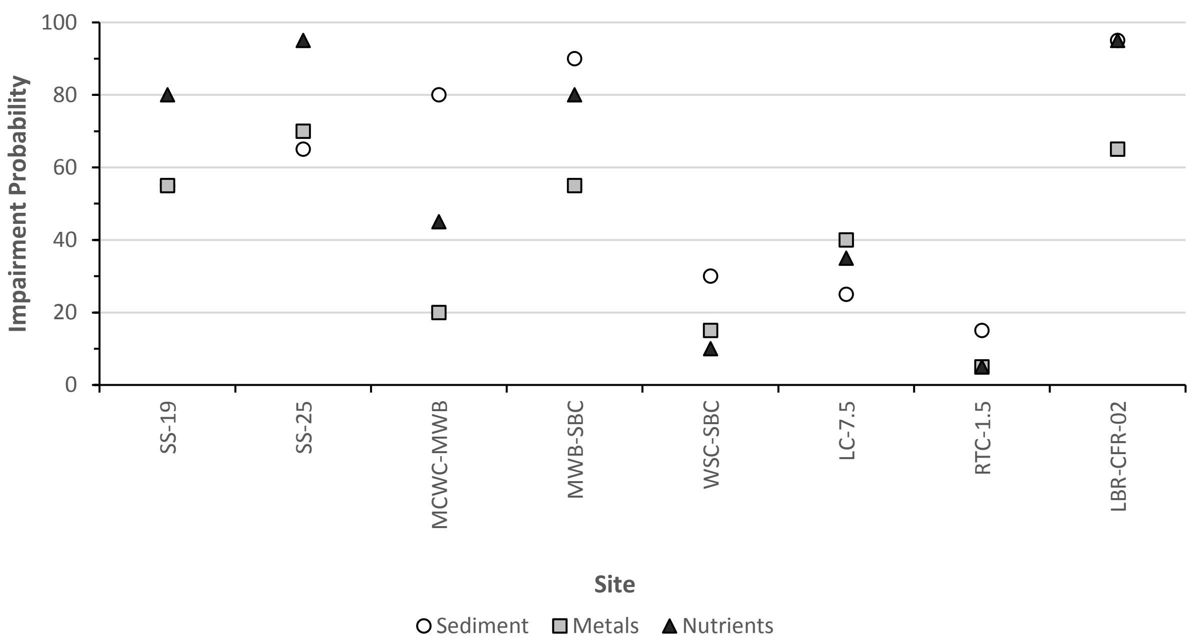

Figure 4-6. Impairment probabilities from specific environmental stressors at each tributary site in the Clark Fork River Operable Unit in 2017 based on relative abundances of stressor-specific diatom increaser taxa.

4.3.2.1.2 Metals

Based on the relative abundance of diatom species considered metals increaser taxa, the probability of impairment from metals in mainstem CFROU sites ranged from 25 percent at Deer Lodge (CFR-27H) to 95 percent at Turah (CFR-116A) (Figure 4-6). Among all mainstem sites, mean metals impairment probability was 63 percent (standard deviation [SD] = 24 percent). All mainstem sites were within one SD of the mean except CFR-27H and CFR-116A. In the tributaries, metals impairment probabilities were highly variable. Impairment probabilities in the Silver Bow Creek were moderately high (55 percent and 70 percent at Frontage Road [SS-19] and at Warm Springs [SS-25], respectively); variable in the Mill-Willow Creek sites (20 percent and 55 percent at Frontage Road [MCWC-MWB] and near mouth [MWB-SBC], respectively); low (not more than 40 percent) in Warm Springs Creek, Lost Creek, and Racetrack Creek; and moderately high (65 percent) in the Little Blackfoot River (Figure 4-6).

Metals impairment probabilities were not related to Q3 (p-value from SLR = 0.6140) or annual average (p-value from SLR = 0.7662) total recoverable COC concentrations.

4.3.2.1.3 Nutrients

Based on the relative abundance of diatom species considered nutrient increaser taxa, the probability of impairment from nutrient in mainstem CFROU sites ranged from 25 percent at Deer Lodge (CFR-27H) to 95 percent at Galen Road (CFR-07D) (Figure 4-6). Impairment probability in the mainstem was high (at least 80 percent) at the three upstream-most sites (near Galen [CFR-03A], at Galen Road [CFR-07D], and at Gemback Road [CFR-11F]); low (25 percent) at Deer Lodge; and moderately high (60-65 percent) at Williams-Tavenner Bridge (CFR-34) and at Turah (CFR-116A). In the tributaries, nutrient impairment probabilities were highly variable. Impairment probabilities in Silver Bow Creek were high (80 percent at Frontage Road [SS-19] and 95 percent at Warm Springs [SS-25]); variable in the Mill-Willow Creek sites (45 percent and 55 percent at Frontage Road [MCWC-MWB] and near mouth [MWB-SBC], respectively); low (not more than 35 percent) in Warm Springs Creek, Lost Creek, and Racetrack Creek; and high (65 percent) in the Little Blackfoot River (Figure 4-6).

Nutrient impairment probabilities were not related to Q3 (p-value from SLR = 0.7632) or annual average (p-value from SLR = 0.5649) total nitrogen concentrations or with Q3 (p-value from SLR = 0.3586) or annual average (p-value from SLR = 0.4621) total phosphorus concentrations.

4.3.2.2 Diatom Association Metrics for Montana Mountain Streams

Biological integrity for all mainstem sites based on Bahls [1993] association metrics were classified as “good” at all sites except Lost Creek (LC-7.5) which was classified as “excellent” (Table 4-3). Despite the “good’ classification, every site had at least minor impairment for two or more metrics, four sites were classified as moderately impaired for a specific metric, and one site was moderately impaired for two metrics (Table 4-3).

Five sites had minor impairment based on the Pollution Index (Table 4-3). All sites were impaired based on the Siltation Index except for the Clark Fork River at Turah (CFR-116A), Lost Creek (LC-7.5), and Racetrack Creek (RTC-1.5) (Table 4-3). Five sites were moderately impaired by the Siltation Index (Table 4-3). Warm Springs Creek (WSC-SBC) and Racetrack Creek (RTC-1.5) had minor impairment based on the Disturbance Index (Table 4-3). Four sites showed minor impairment due to the high Dominant Taxon percentage, and all of those sites also showed minor impairment due to low Shannon Diversity (Table 4-3). Every site except Racetrack Creek had minor impairment based on the Abnormal Cells metric and one site in Silver Bow Creek (SS-19) had moderate impairment (Table 4-3).

Table 4-3. Diatom association metrics, biological integrity and impairment ratings for Clark Fork River Operable Unit monitoring sites, 2017 (after Bahls [1993]).

Site ID	Site Location	Diatom Species Richness	Shannon Diversity Index	Pollution Index	Siltation Index	Disturbance Index	Dominant Taxon (%)	Abnormal Cells (%)	Biological Integrity
Mainstem Sites									
CFR-03A	Clark Fork River near Galen	57	3.02	2.58	49	4.1	17	0.8	good
CFR-07D	Clark Fork River at Galen Road	52	2.81	2.68	30	2.5	26	0.9	good
CFR-11F	Clark Fork River at Gemback Road	61	3.07	2.54	41	2.0	23	0.6	good
CFR-27H	Clark Fork River at Deer Lodge	64	3.31	2.46	44	16.4	16	0.8	good
CFR-34	Clark Fork River at Williams-Tavenner Bridge	52	3.10	2.46	44	3.8	14	1.3	good
CFR-116A	Clark Fork River at Turah	56	2.99	2.70	16	5.0	23	1.0	good
Tributary Sites									
SS-19	Silver Bow Creek at Frontage Road	50	2.90	2.15	59	0.9	12	4.6	good
MCWC-MWB	Mill-Willow Creek at Frontage Road	66	3.34	2.52	34	16.6	17	1.1	good
MWB-SBC	Mill-Willow Bypass near mouth	55	2.99	2.61	25	2.8	25	1.3	good
SS-25	Silver Bow Creek at Warm Springs	55	3.14	2.49	33	1.8	17	1.4	good
WSC-SBC	Warms Springs Creek near mouth	60	2.68	2.72	26	43.3	43	0.4	good
LC-7.5	Lost Creek near mouth	75	3.40	2.63	19	18.4	18	0.5	excellent
RTC-1.5	Racetrack Creek near mouth	43	2.19	2.50	4	28.3	28	0.0	good
LBR-CFR-02	Little Blackfoot River at Beck Hill Road	62	2.90	2.67	22	1.8	27	1.0	good

Result suggests minor impairment.

Result suggests moderate impairment.

Result suggests severe impairment.

4.3.2.3 Freshwater Diatoms as Ecological Indicators

4.3.2.3.1 Inorganic Nutrient Tolerance

The relative abundance of nutrient-tolerant species in the Clark Fork River mainstem ranged from 64 percent at Deer Lodge (CFR-27H) to 84 percent at Williams-Tavenner Bridge (CFR-34) (Figure 4-7). Mean relative abundance of nutrient-tolerant species was 73 percent (SD = 8 percent). All mainstem sites had relative abundance of nutrient-tolerant species within one SD of the mainstem mean except CFR-27H (1.1 SD below the mainstem mean) and CFR-34 (1.3 SD above the SD mainstem mean). In the tributaries, relative abundance ranged from 8 percent in Racetrack Creek (RTC-1.5) to 90 percent in Silver Bow Creek at Frontage Road (SS-19) (Figure 4-7). Mean relative abundance in the tributaries was 59 percent (SD = 30 percent). All tributary sites had relative abundance within one SD of the tributary mean except Warm Springs Creek (WSC-SBC) and RTC-1.5 (1.0 SD and 1.7 SD below the tributary mean, respectively) and SS-19 (1.1 SD above the tributary mean).

The relative abundance of nutrient-intolerant species in the Clark Fork River mainstem ranged from 1.6 percent at Williams-Tavenner Bridge (CFR-34) to 4.9 percent at Turah (CFR-116A) (Figure 4-8). Mean relative abundance of nutrient-intolerant species was 3.2 percent (SD = 1.3 percent). All mainstem sites had relative abundance of nutrient-intolerant species within one SD of the mainstem mean except CFR-34 (1.3 SD below the mainstem mean) and CFR-116A (1.3 SD above the SD mainstem mean). In the tributaries, relative abundance ranged from 1.3 percent in Silver Bow Creek at Frontage Road (SS-19) to 20.8 percent in Racetrack Creek (RTC-1.5) (Figure 4-8). Mean relative abundance in the tributaries was 6.8 percent (SD = 6.5 percent). All tributary sites had relative abundance within one SD of the tributary mean except RTC-1.5 which was 2.1 SD above the tributary mean.

Relative abundance of nutrient-tolerant species was not related to Q3 (p-value from SLR = 0.2724) or average annual (p-value from SLR = 0.2614) inorganic nitrogen concentrations. Relative abundance of nutrient-intolerant species was also not related to Q3 (p-value from SLR = 0.0817) or annual average (p-value from SLR = 0.0981) inorganic nitrogen concentrations.

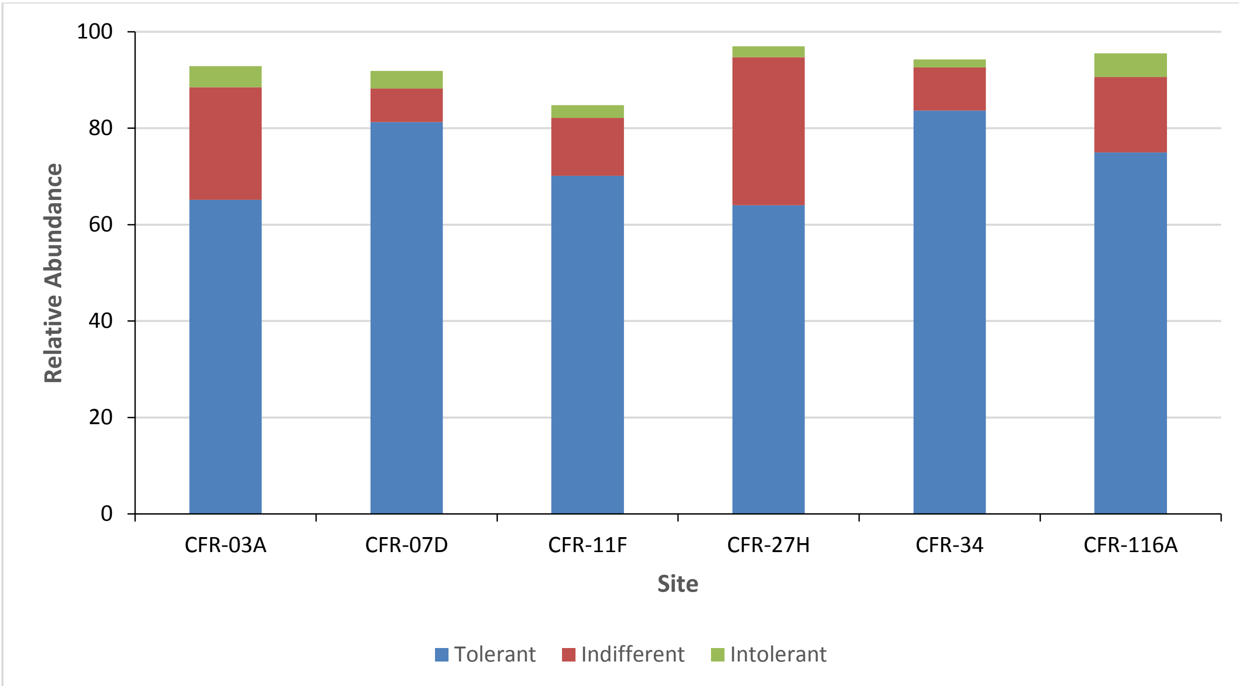

Figure 4-7. Relative abundance of diatoms classified in relation to tolerance to inorganic nutrients (after Van Dam et al. [1994]) in mainstem sites of the Clark Fork River Operable Unit, 2017.

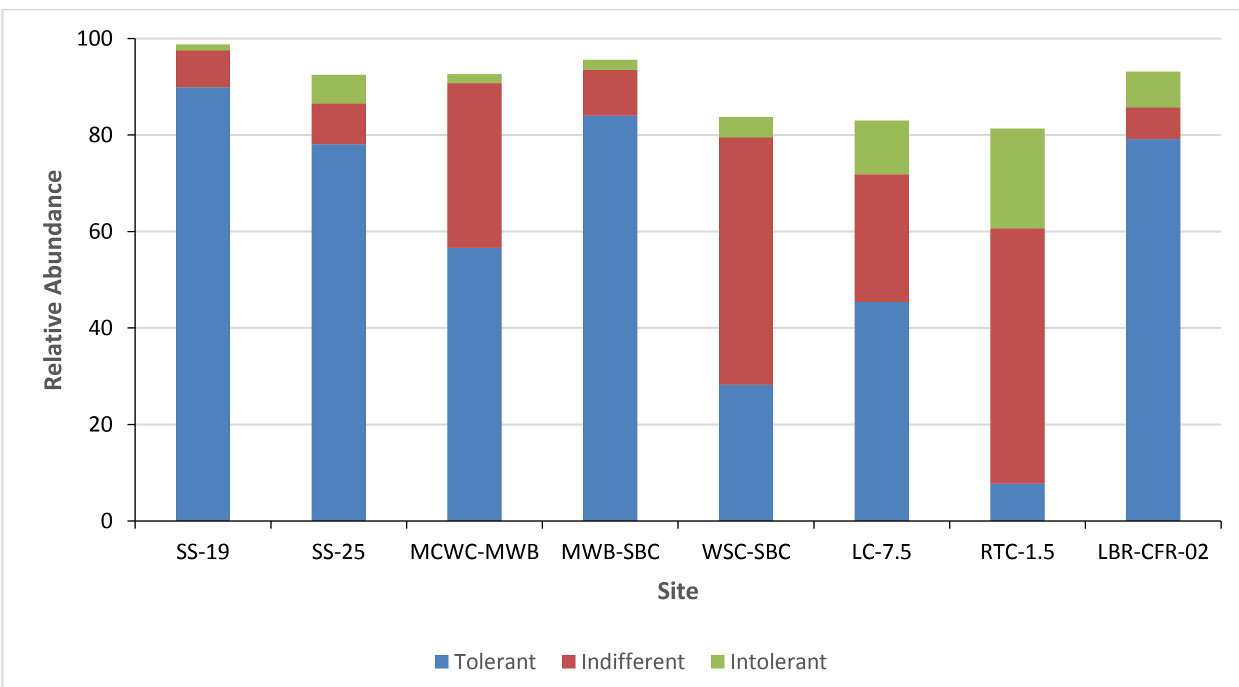

Figure 4-8. Relative abundance of diatoms classified in relation to tolerance to inorganic nutrients (after Van Dam et al. [1994]) in tributaries of the Clark Fork River Operable Unit, 2017.

4.3.2.3.2 Trophic State

The relative abundance of nitrogen-heterotroph species in the Clark Fork River mainstem ranged from 5.9 percent at Turah (CFR-116A) to 17.0 percent at Williams-Tavenner Bridge (CFR-34) (Figure 4-9). Mean relative abundance of nitrogen-heterotroph species in the mainstem was 10.6 percent (SD = 4.9 percent). All mainstem sites had relative abundance of nitrogen-heterotroph species within one SD of the mainstem mean except at Deer Lodge (CFR-27H; 1.1 SD above the mainstem mean), CFR-34 (1.3 SD above the mainstem mean), and CFR-116A (1.0 SD below the mainstem mean). In the tributaries, relative abundance of nitrogen-heterotroph species ranged from 1.8 percent in Racetrack Creek (RTC-1.5) to 51 percent in Silver Bow Creek at Frontage Road (SS-19) (Figure 4-9). Mean relative abundance of nitrogen-heterotroph species in the tributaries was 13.5 percent (SD = 16.6 percent). All tributary sites had relative abundance of nitrogen-heterotroph species within one SD of the tributary mean except SS-19 (2.3 SD above the tributary mean).

The relative abundance of nitrogen-autotroph, sensitive species in the Clark Fork River mainstem ranged from 6.1 percent at Deer Lodge (CFR-27H) to 37.9 percent at Turah (CFR-116A) (Figure 4-10). Mean relative abundance of nitrogen-autotroph, sensitive species in the mainstem was 23.4 percent (SD = 10.7 percent). All mainstem sites had relative abundance of nitrogen-autotroph, sensitive species within one SD of the mainstem mean except CFR-27H (1.6 SD below the mainstem mean) and CFR-116A (1.4 SD above the mainstem mean). In the tributaries, relative abundance of nitrogen-autotroph, sensitive species ranged from 5.8 percent in Silver Bow Creek at Frontage Road (SS-19) to 27.1 percent in the Little Blackfoot River (LBR-CFR-02) (Figure 4-10). Mean relative abundance of nitrogen-autotroph, sensitive species in the tributaries was 14.5 percent (SD = 8.7 percent). All tributary sites had relative abundance of nitrogen-autotroph, sensitive species within one SD of the tributary mean except SS-19 (1.0 SD below tributary mean) and LBR-CFR-02 (1.5 SD above the tributary mean).

Relative abundance of nitrogen-heterotroph (i.e., organic nitrogen tolerant) species were positively related to Q3 (p-value from SLR = 0.0160; r^2 = 0.4559) organic nitrogen concentrations. Based on the model fit, relative abundance of nitrogen-heterotroph species increased by 10 percent for every 0.1 mg/L increase in Q3 organic nitrogen concentration. Relative abundance of nitrogen-heterotroph species were also positively related to annual average (p-value from SLR = 0.0106; r^2 = 0.4955) organic nitrogen concentrations. Based on the model fit, relative abundance of nitrogen-heterotroph species increased by 15 percent for every 0.1 mg/L increase in annual average organic nitrogen concentration.

Relative abundance of nitrogen-autotroph species sensitive to organic nitrogen concentrations was not related to Q3 (p-value from SLR = 0.7325) or annual average (p-value from SLR = 0.7223) organic nitrogen concentrations.

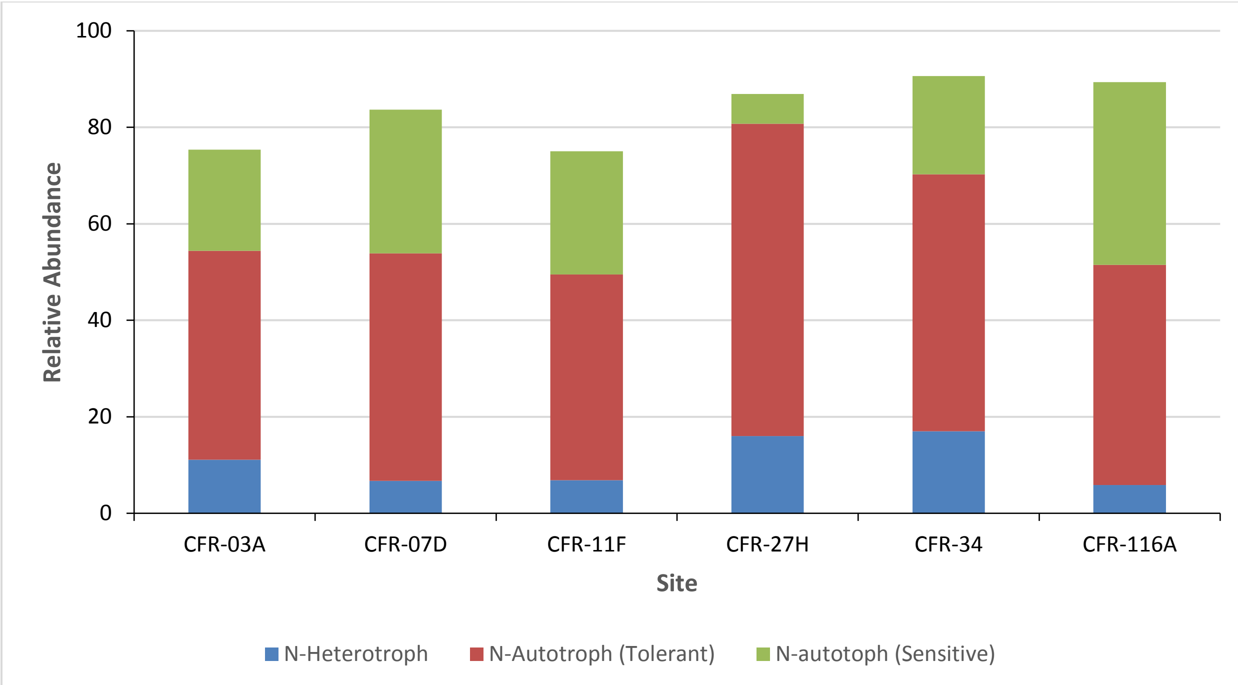

Figure 4-9. Relative abundance of diatoms classified in relation to trophic state (after Van Dam et al. [1994]) in the mainstem sites of the Clark Fork River Operable Unit, 2017.

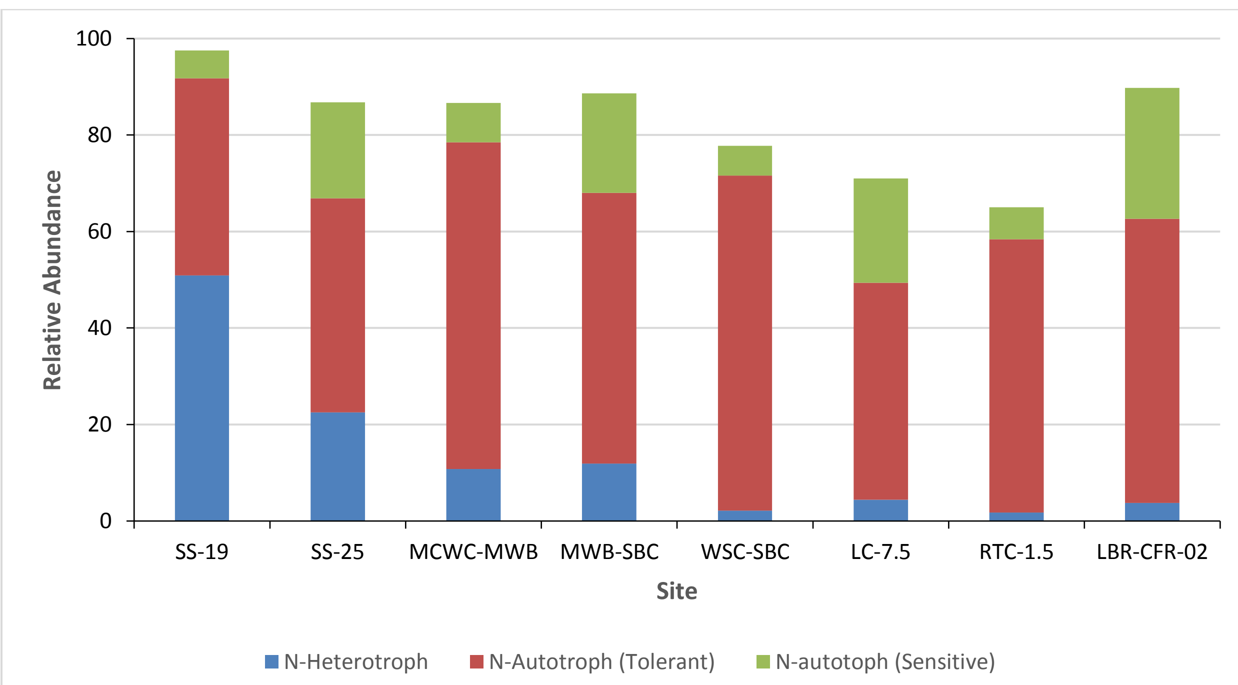

Figure 4-10. Relative abundance of diatoms classified in relation to trophic state (after Van Dam et al. [1994]) in tributaries of the Clark Fork River Operable Unit, 2017.

4.3.2.3.3 Saprobity and Hypoxia

The relative abundance of oligosaprobous or ß-mesosaprobous species in the Clark Fork River mainstem ranged from 68 percent at Turah (CFR-116A) to 82 percent at Galen Road (CFR-07D) (Figure 4-11). Mean relative abundance of oligosaprobous or ß-mesosaprobous species in the mainstem was 76 percent (SD = 5 percent). All mainstem sites had relative abundance of oligosaprobous or ß-mesosaprobous species within one SD of the mainstem mean except at CFR-07D (1.4 SD above the mainstem mean) and CFR-116A (1.7 SD below the mainstem mean). In the tributaries, relative abundance of oligosaprobous or ß-mesosaprobous species ranged from 39 percent in Racetrack Creek (RTC-1.5) to 84 percent in the Little Blackfoot River (LBR-CFR-02) (Figure 4-11). Mean relative abundance of oligosaprobous or ß-mesosaprobous species in the tributaries was 65 percent (SD = 15 percent). All tributary sites had relative abundance of oligosaprobous or ß-mesosaprobous species within one SD of the tributary mean except Silver Bow Creek at Frontage Road (SS-19; 1.1 SD below the tributary mean), RTC-1.5 (1.7 SD above the tributary mean), and LBR-CFR-02 (1.3 SD above the tributary mean).

The relative abundance of oxygen-sensitive species in the Clark Fork River mainstem ranged from 46 percent near Galen (CFR-03A) to 65 percent at Williams-Tavenner Bridge (CFR-34) (Figure 4-12). Mean relative abundance of oxygen-sensitive species in the mainstem was 57 percent (SD = 7 percent). All mainstem sites had relative abundance of oxygen-sensitive species within one SD of the mainstem mean except CFR-03A (1.6 SD below the mainstem mean) and CFR-34 (1.1 SD above the mainstem mean). In the tributaries, relative abundance of oxygen-sensitive species ranged from 38 percent Racetrack Creek (RTC-1.5) to 67 percent in Warm Springs Creek (WSC-SBC) (Figure 4-12). Mean relative abundance of oxygen-sensitive species in the tributaries was 49 percent (SD = 10 percent). All tributary sites had relative abundance of oxygen-sensitive species within one SD of the tributary mean except WSC-SBC (1.8 SD above tributary mean) and RTC-1.5 (1.1 SD below the tributary mean).

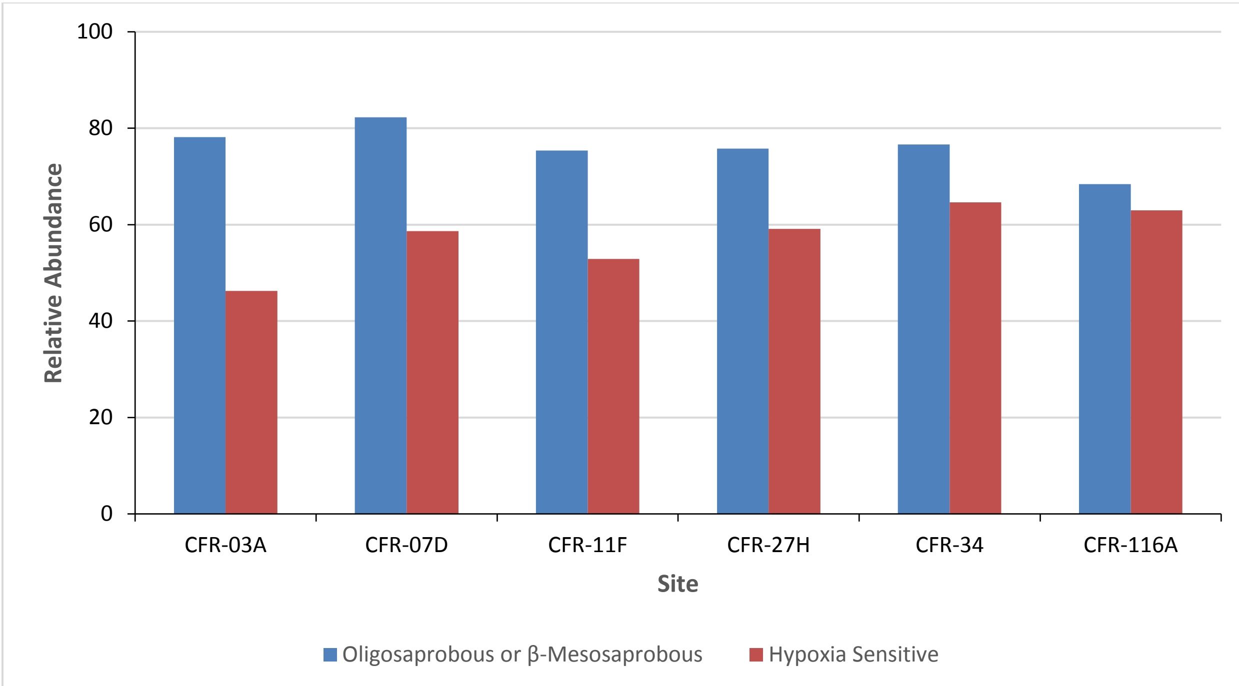

Figure 4-11. Relative abundance of diatoms classified in relation to saprobity and oxygen sensitivity (after Van Dam et al. [1994]) in the mainstem of the Clark Fork River Operable Unit, 2017.

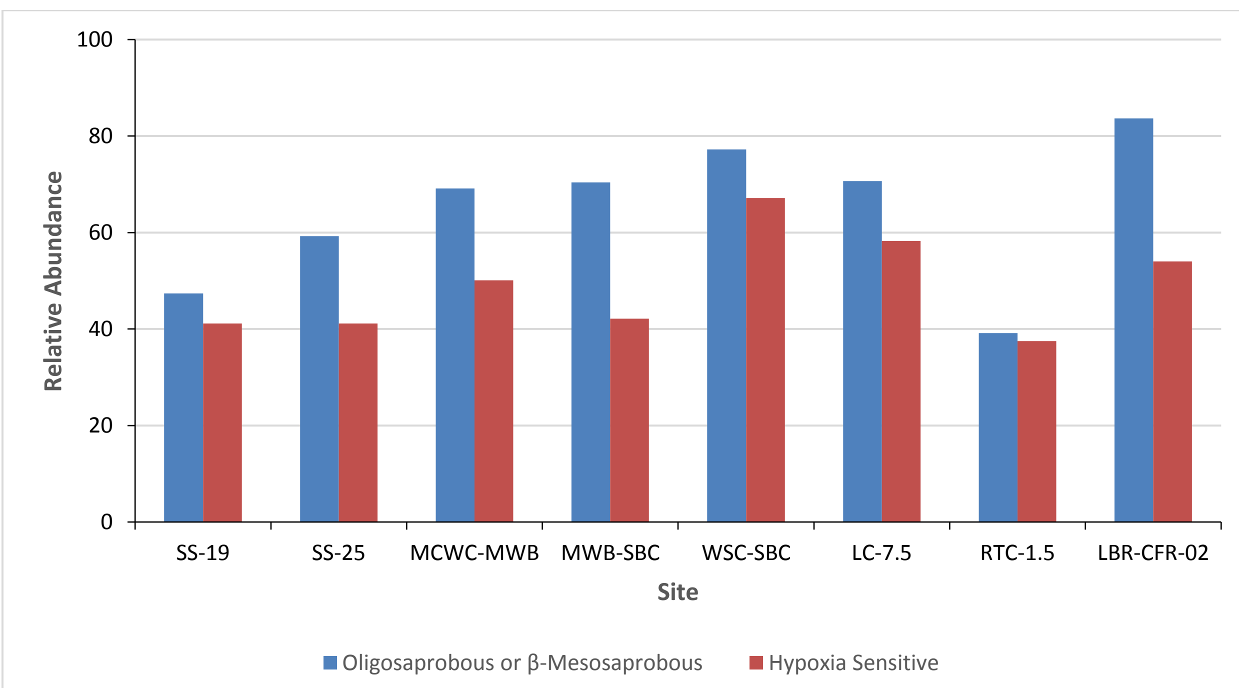

Figure 4-12. Relative abundance of diatoms classified in relation to saprobity and oxygen sensitivity (after Van Dam et al. [1994]) in the tributaries of the Clark Fork River Operable Unit, 2017.

4.4 DISCUSSION

4.4.1 Ecological Interpretations of Periphyton Assemblages

4.4.1.1 Clark Fork River

4.4.1.1.1 Clark Fork River near Galen (CFR-03A)

Six genera of blue-green algae were present at Site CFR-03A and estimated biovolume was strongly dominated by the blue-green algae, particularly the colonial form *Nostoc* and the filamentous form *Dichothrix*. The filamentous green algae *Cladophora* and *Oedogonium* were also high in estimated biovolume. These algae indicate nutrient enrichment and the blue-green taxa suggest limited nitrogen relative to phosphorus.

Diatom species richness and Shannon diversity at CFR-03A was similar to other mainstem sites. Dominant diatom taxa included *Cocconeis placentula, Epithemia sorex* and *Navicula cryptotenella*. Included in these taxa are forms often associated with, or epiphytic on, filamentous green algae. For the most part these taxa suggest cool, alkaline water that is moderately rich in inorganic nutrients. The relative importance of *Epithemia sorex,* along with the dominance of the blue-green alga *Nostoc*, suggest nitrogen was limited relative to phosphorus.

Two separate sediment impairment bioassessment tools indicated impairment form sediment at CFR-03A. The probability of impairment from sediment based on the increaser diatom taxa was 90 percent and the Siltation Index indicated moderate impairment from siltation. These results are counterintuitive because the site's proximity to the Warm Springs Pond system, which sequesters sediment from Silver Bow Creek, presumably reduces sediment loads and siltation at CFR-03A. Moreover, surface water monitoring in 2017 demonstrated that this site actually had the lowest total suspended sediment concentrations of all mainstem sites. Impairment from nutrients and metals was considered moderate and biological integrity at Site CFR-03A was rated as "good.

4.4.1.1.2 Clark Fork River at Galen Road (CFR-07D)

Seven genera of non-diatom algae were identified at CFR-07D: four genera of green algae and three genera of blue-green algae. Estimated biovolume was similar between the green algae and blue-green algae. The filamentous green algae *Cladophora* and *Oedogonium* were common as well as the blue-green algae *Tolypothrix* and *Nostoc*. The algal assemblage at Site CFR-07D differed from upstream Site CFR-03A most notably by the appearance of *Tolypothrix*, and the decreased importance of *Nostoc* relative to *Cladophora*. The non-diatom algae assemblage at CFR-07D suggest water moderately rich in inorganic nutrients and possibly limited by inorganic nitrogen.

Diatom species richness and Shannon Diversity were slightly lower at Site CFR-07D compared to other mainstem sites (i.e., 1.0 and 1.5 SD below the mainstem mean for each metric, respectively) suggesting some degree of overall impairment at the site. *Cocconeis placentula* and *Epithemia sorex* were abundant at both sites. *Epithemia sorex* was the dominant species exceeding 25 percent relative abundance. The epiphytic diatom *Cocconeis pediculus* was relatively abundant at site CFR-07D, possibly due to the abundance of *Cladophora* which provided abundant habitat for *Cocconei*s *pediculus*. The diatom assemblage at Site CFR-07D generally indicated cool, somewhat alkaline water, with moderately high levels of inorganic nutrients that may be nitrogen-limited.

The diatom assemblage indicated a high probability of impairment from sediment (90 percent) and nutrients (95 percent) in general but also relative to other mainstem sites based on increaser taxa indices. However, other indices contradicted those results. The relative abundance of nutrient-tolerant diatoms was relatively low, and the relative abundance and the Siltation Index indicated only minor impairment. Impairment from metals was likely (80 percent). However, despite these disturbances, biological integrity was rated "good" overall.

4.4.1.1.3 Clark Fork River at Gemback Road (CFR-11F)

Thirteen genera of non-diatom algae were identified at Site CFR-11F: eight genera of green algae, four genera of blue-green algae and one genus of red algae. *Cladophora*, *Tolypothrix,* and *Nostoc* were common. Green algae dominated the sample biovolume. The non-diatom algae assemblage suggested water moderately rich in inorganic nutrients but nitrogen-limited.

Diatom species richness and Shannon diversity at CFR-11F was similar to other mainstem sites. Dominant diatom taxa included *Cocconeis placentula, Epithemia sorex, Navicula cryptotenella, Nitzschia archibaldii* and *N. incognita*. *Epithemia sorex* relative abundance was almost 25 percent. *Cocconeis placentula* was also abundant. These species prefer water with low to moderate levels of inorganic nitrogen and phosphorus and moderate conductivity, and occur as epiphytes on, or in close association with, filamentous green algae.

Multiple bioassessment scores indicated that the diatom assemblage at CFR-11F was similar to the Clark Fork River mean for many of the indices. Probabilities of impairment from sediment, metals, and nutrients based on increaser taxa relative abundance, relative abundance of nutrient-tolerant and -intolerant species, relative abundance of nitrogen-heterotroph and nitrogen-autotroph/sensitive species, and the relative abundance of oligosaprobous or ß-mesosaprobous and hypoxia-sensitive species were all similar to the Clark Fork River mainstem average. For those indices, the mainstem averages were: impairment probabilities of 62 percent (sediment), 63 percent (metals), and 69 percent (nutrients); species relative abundances of 73 percent (nutrient-tolerant), 3 percent (nutrient-intolerant), 11 percent (nitrogen-heterotroph), 23 percent (nitrogen-autotroph/sensitive), 76 percent (oligosaprobous or ß-mesosaprobous) and 57 percent (hypoxia-sensitive). The Siltation Index also suggested moderate impairment. Biological integrity at Site CFR-11F in 2017 was rated "good".

4.4.1.1.4 Clark Fork River at Deer Lodge (CFR-27H)

Eleven genera of non-diatom algae were identified at Site CFR-27H: with eight genera of green algae and three genera of blue-green algae. The filamentous blue-green algae *Phormidium* and the filamentous green alga *Cladophora* were abundant. Green and blue-green algae dominated biovolume in the sample. The total absence of the nitrogen-fixing blue-green alga *Nostoc* and the low abundance of the diatom *Epithemia sorex* suggest that inorganic nitrogen was not limited relative to phosphorus.

Diatom species richness and Shannon Diversity were higher at Site CFR-27H compared to other mainstem sites (i.e., 1.2 SD and 1.6 SD above the mainstem mean for each metric, respectively) suggesting better overall conditions at the site compared to other mainstem sites. This result is somewhat counterintuitive because metal concentrations tend to be high at this site compared to other sites in the mainstem (see Chapter 2.0). Common diatom species at the site included: *Achnanthidium minutissimum*, followed by *Nitzschia dissipata, Navicula cryptotenella, Cocconeis placentula, Nitzschia archibaldii, Amphora pediculus,* and *Stephanocyclus meneghiniana*. These diatom species generally prefer cool, somewhat alkaline water with low to moderate levels of inorganic nitrogen and phosphorus and moderate conductivity. The dominance of *Achnanthidium minutissimum* suggests environmental instability, possibly related to streamflow or water temperature.

Bioassessment scores were highly variable, and often contradictory, at CFR-27H. Probabilities of impairment predicted from metals and nutrients based on increaser taxa relative abundance were low relative to other mainstem sites (i.e., 1.6 SD and 1.7 SD below the mainstem mean for each, respectively) and similarly the relative abundance of nutrient-tolerant species was low relative to other mainstem sites (1.1 SD below the mainstem mean) suggesting relatively little impairment from metals and nutrients at the site compared to other mainstem sites. However, the relatively high relative abundance of nitrogen-heterotroph species (1.1 SD above mainstem mean) combined with the low relative abundance of nitrogen-autotroph/sensitive species (1.6 SD below the mainstem mean) suggest impairment from nutrient enrichment. The Siltation Index suggested moderate impairment. Despite the volatility of the bioassessment results, overall biological integrity at Site CFR-27H was rated as “good”.

4.4.1.1.5 Clark Fork River at Williams-Tavenner Bridge (CFR-34)

Ten genera of non-diatom algae were present at Site CFR-34: seven genera of green algae and three genera of blue-green. The filamentous green alga *Cladophora,* colonial blue-green alga *Nostoc*, and filamentous blue-green alga *Dichothrix* were common. Green algae were dominant in over blue-green algae. *Cladophora* and the other six genera of green algae indicate water moderately rich in inorganic nutrients and the blue-green algae *Nostoc* and *Dichothrix* suggest nitrogen may have been the limiting nutrient.

Diatom species richness was slightly lower at Site CFR-34 compared to other mainstem sites (i.e., 1.0 SD below the mainstem mean) but Shannon Diversity was similar to other mainstem sites. Dominant diatom taxa included *Epithemia sorex, Nitzschia dissipata, Cocconeis pediculus* and *C. placentula*. These diatoms prefer cool, well-oxygenated, alkaline water of moderate conductivity, with low to moderate levels of inorganic nutrients.

Bioassessment scores were variable, and often contradictory, at CFR-34. Probabilities of impairment predicted from sediment, metals and nutrients were similar to the mean for the mainstem suggesting impairment from each of those stressors was likely. The relative abundance of nutrient-tolerant and nutrient-intolerant species suggested enrichment at levels exceeding that of other mainstem sites. Nutrient-tolerant species were more common (1.3 SD above the mainstem mean) and nutrient-intolerant species were less common (1.3 SD below the mainstem mean) compared to other mainstem sites. Hypoxia-sensitive species were more common than in other mainstem sites (1.1 SD above the mainstem mean). The Siltation Index suggested moderate impairment. Overall biological integrity at Site CFR-34 was rated as "good.

4.4.1.1.6 Clark Fork River at Turah (CFR-116A)

Seventeen genera of non-diatom algae were identified at Site CFR-116A including nine genera of green algae, six genera of blue-green algae, one genus of yellow-green algae, and one genus of red algae. The filamentous green algae *Cladophora* and *Ulothrix,* the red alga *Audouinella, and the* colonial blue-green genus *Nostoc* were common. Green algae dominated the sample followed by blue-green algae. The non-diatom algae assemblage at Site CFR-116A was generally indicative of cool, nutrient-rich water.

Diatom species richness and Shannon Diversity at CFR-116A was similar to other mainstem sites. Six diatom taxa were common including *Cymbella affinis* (which was dominant at about 23 percent relative abundance), *Diatoma moniliformis, Epithremia sorex, Diatoma vulgaris*, and *Achnanthidium minutissimum* and *Gomphonema pumilum*. These diatom taxa in general prefer cool, well-oxygenated, moderately alkaline water with relatively low to moderate levels of nutrients.

Bioassessment scores on the whole suggested less impaired conditions at CFR-116A compared to other mainstem sites with the exception of metals impairment probability and oligosaprobous or ß-mesosaprobous species relative abundance. Metals impairment probability was 1.4 SD above the mainstem mean despite generally low metals concentrations in surface water (see Chapter 2.0) and sediment (see Chapter 3.0) at this site. Relative abundance of oligosaprobous or ß-mesosaprobous species was 1.7 SD below the mainstem mean indicating that species intolerant of habitats with a high degree of organic decomposition were rare. Biological integrity at Site CFR-116A was rated "good".

4.4.1.2 Silver Bow Creek

4.4.1.2.1 Silver Bow Creek at Frontage Road (SS-19)

Nine genera of non-diatom algae were identified at Site SS-19 including six genera of green algae and three genera of blue-green algae. Green algae accounted for most the estimated biovolume specifically the filamentous green algae *Cladophora* and *Stigeoclonium*. Blue-green algae were considerably less important than the green algae.

Diatom species richness and Shannon diversity at SS-19 was similar to other tributary sites. Dominant diatom taxa included *Nitzschia paleacea*, *Cocconeis placentula*, *Mayamaea atomus*, *Nitzschia inconspicua,* and *Staurosira construens var. binodis*.

Several bioassessment scores suggested more impaired conditions at SS-19 than at other tributary sites particularly for nutrients. Relative abundances of nutrient-tolerant species and nitrogen-heterotroph species were 1.1 SD and 2.25 SD above the tributary mean, respectively. Other results supporting the conclusion that the site is nutrient impaired included the scarcities of nitrogen-autotroph/sensitive species and oligosaprobous or ß-mesosaprobous species which each had relative abundances of 1.0 SD and 1.1 SD below tributary mean, respectively. Despite consistent evidence of nutrient impairment, biological integrity at Site SS-19 was rated "good".

4.4.1.2.2 Silver Bow Creek at Warm Springs (SS-25)

Eight genera of non-diatom algae were identified at Site SS-25 including seven genera of green algae and one genus of blue-green algae. The filamentous genera *Cladophora* and *Oedogonium* had the highest biovolume. The colonial blue-green alga *Microcystis,* a planktonic form that likely originated in the Warm Springs Ponds, was the only blue-green genera identified at Site SS-25. The non-diatom algae present at Site SS-25 were indicative of water relatively rich in nutrients, particularly nitrogen, and are relatively tolerant of metals.

Diatom species richness and Shannon diversity at SS-25 was similar to other tributary sites. Dominant diatom taxa at Site SS-25 included *Cocconeis placentula, Epithemia sorex, Nitzschia fonticola,* and *Nitzschia paleacea*. Several of these diatom taxa commonly occur as epiphytes or in association with filamentous green algae and aquatic macrophytes in alkaline, nutrient-rich streams. *Epithemia sorex* is known to flourish in relatively low nitrogen to phosphorus ratio due to nitrogen fixation by endosymbiotic blue-green algae.

Two bioassessment scores suggested more impaired conditions at SS-25 than at other tributary sites. The impairment probabilities for metals and nutrients based on relative abundance of increaser taxa were 1.2 SD and 1.1 SD higher than the tributary mean for each, respectively. All other bioindex values were similar to the tributary mean. Biological integrity at Site SS-25 was rated as "good.

4.4.1.3 Mill-Willow Creek

4.4.1.3.1 Mill Willow Creek at the Mill-Willow Bypass (MCWC-MWB)

Eight genera of non-diatom algae were present at Site MCWC-MWB including four genera of green algae, three genera of blue-green algae, and one genus of red algae. The filamentous green alga *Cladophora*, the colonial blue-green alga *Nostoc,* the filamentous red alga *Audouinella* and the filamentous blue-green alga *Tolypothrix* were the most important non-diatom algae at the. These taxa indicate relatively unimpaired water quality at Site MCWC-MWB, with moderately high levels of inorganic nutrients, and likely nitrogen limitation.

Diatom species richness and Shannon Diversity at MCWC-MWB was similar to other tributary sites. Dominant diatom taxa included *Achnanthidium minutissimum, Cocconeis placentula,* and *Nitzschia archibaldii.* Based on this species composition, the local habitat was likely cool, moderately nutrient-rich, alkaline water.

All bioassessment scores were similar to the tributary mean at Site MCWC-MWB. Overall biological integrity at Site MCWC-MWB in 2017 was rated as "good".

4.4.1.3.2 Mill Willow Bypass near Mouth (MWB-SBC)

Nine genera of non-diatom algae were identified at Site MWB-SBC including six genera of green algae and three genera of blue-green algae. Green algae were most dominant in sample biovolume, particularly *Oedogonium* and *Cladophora.* The most common blue-green genera were *Tolypothrix, Nostoc,* and *Phormidium*. Moderate enrichment by inorganic nutrients, particularly nitrogen, was indicated by the non-diatom alga assemblage.

Diatom species richness and Shannon diversity at MWB-SBC was similar to other tributary sites. Dominant diatoms at Site MWB-SBC included *Cocconeis pediculus, C. placentula, Cymbella affinis, Epithemia sorex, Navicula capitatoradiata,* and *Stephanocyclus meneghiniana.* These diatom species indicated cool, alkaline water that were moderately rich in nutrients, but possibly limited by nitrogen.

Most bioassessment scores were similar to the tributary mean at Site MWB-SBC. One exception was the sediment impairment probability (90 percent) which was 1.1 SD above the tributary mean. The Siltation Index score also supported the conclusion of sediment impairment with a result of "moderate" to "high" probability of impairment from sediment. Despite the evidence of sediment impairment, overall biological integrity at Site MWB-SBC was rated as "good".

4.4.1.4 Warm Springs Creek

Eleven genera of non-diatom algae were identified in Warm Springs Creek including five genera of green algae, four genera of blue-green algae, one genera each of red and yellow-green algae. Green algae were dominant in sample biovolume followed by blue-green algae. The blue-green algae *Nostoc*, *Oedogonium, Cladophora* and *Ulothrix* had a high proportion of biovolume in the sample. The filamentous red alga *Audouinella* and the filamentous yellow-green alga *Vaucheria* were also relatively voluminous. All these algae are indicative of cool, relatively unpolluted water with moderate levels of inorganic nutrients. The relative importance of *Nostoc* suggests that inorganic nitrogen may have been the limiting nutrient relative to phosphorus although that conclusion is contradicted by the abundance of green algae.

Diatom species richness and Shannon diversity in Warm Springs Creek was similar to other tributary sites. Only two diatom taxa (*Achnanthidium minutissimum* and *Nitzschia dissipata)* were common indicating high species evenness at this site. However, the relatively high abundance of *Achnanthidium minutissimum* suggests increased environmental stress as was demonstrated in the elevated Disturbance Index value.

Multiple bioassessment scores suggested conditions that were less impaired in Warm Springs Creek compared to other tributary sites. The metals (15 percent) and nutrient (10 percent) impairment probabilities derived from the relative abundance of increaser taxa were 1.0 SD and 1.2 SD below the tributary mean, respectively. In addition, the relative abundance of nutrient-tolerant species (28 percent) 1.0 SD below the tributary mean and the relative abundance of hypoxia-sensitive species was 1.8 SD above the tributary mean. These results suggest, at least compared to other tributary sites, Warm Springs Creek had lower nutrient and metal concentrations and less hypoxia than other sites. Biological integrity was rated as “good.

4.4.1.5 Lost Creek

Nine genera of non-diatom algae were present in Lost Creek including seven genera of green algae, one genus of blue-green algae, and one genus of red algae. Four genera of filamentous green algae (*Chara, Cladophora, Mougeotia,* and *Oedogonium*) were common. Green algae dominated biovolume in the sample. The filamentous red alga *Audouinella* was also common as was the blue-green taxon *Phormidium*. These taxa are indicative of cool, high quality water that is relatively high in dissolved minerals, and moderately rich in inorganic nutrients.

Diatom species richness and Shannon Diversity were higher in Lost Creek compared to other tributary sites (i.e., 17 SD and 1.2 SD above the tributary mean for each metric, respectively) suggesting better overall conditions at the site compared to other tributary sites. Dominant diatoms included *Achnanthidium minutissimum, Encyonopsis microcephala, E. minuta, Staurosira construens* var. *pumila* and *S. construens* var. *venter*. These taxa prefer cool, well-oxygenated, alkaline water of moderate conductivity, with low to moderate inorganic nutrients.

Most bioassessment scores suggested conditions that similar in Lost Creek to other tributaries. However, the sediment impairment probability (25 percent) from the relative abundance of increaser taxa was 1.0 SD below the tributary mean. The Siltation Index result also supported the conclusion that the site is unimpaired by sediment. Biological integrity in Lost Creek was rated as “excellent”.

4.4.1.6 Racetrack Creek

Twelve non-diatom genera were observed in Racetrack Creek including ten genera of green algae, and one genus each of blue-green algae and red algae. The filamentous red alga *Audouinella* dominated estimated algal biovolume. The filamentous green algae *Ulothrix* and *Microspora* were also common. These taxa are indicative of cool, high quality water of circumneutral pH that is moderately rich in nutrients, with low-to-moderate concentrations of dissolved solids.

Diatom species richness (43) and Shannon Diversity (2.19) in Racetrack Creek were the lowest of any CFROU site monitored in 2017 and were 1.5 SD and 1.7 SD below the tributary mean, respectively. These results suggest overall impairment at the site. Dominant diatom taxa included *Achnanthidium minutissimum* (28 percent) and *A. pyrenaicum, Encyonema fogedii,* and *E. silesiacum*. These taxa all prefer cool water with low-to-moderate conductivity and inorganic nutrient levels. *Achnanthidium minutissimum* is well adapted to recolonizing recently disturbed substrates, and as such is the basis for the Disturbance Index. The dominance of *Achnanthidium minutissimum* suggests that physical factors such as high current velocities, substrate scour, or dewatering may have impacted the periphyton assemblage.

Bioassessment scores tended toward the extremes in Racetrack Creek. Five indices suggested conditions that were less impaired than on average in the tributaries. Impairment probability estimates for sediment (15 percent), metals (5 percent), and nutrients (5 percent) were all 1.4-1.5 SD below the tributary mean. In addition, the low relative abundance of nutrient-tolerant species (8 percent; 1.7 SD below tributary mean) and high relative abundance of nutrient-intolerant species (21 percent; 2.1 SD above tributary mean) strongly suggest conditions unimpaired by nutrient enrichment. However, other indices indicate high saprobity (relative abundance of oligosaprobous or ß-mesosaprobous was 39 percent or 1.7 SD below tributary mean) and hypoxia (relative abundance of hypoxia-sensitive species was 38 percent or 1.1 SD below the tributary mean). Overall biological integrity in Racetrack Creek was rated as "good".

4.4.1.7 Little Blackfoot River

Nineteen non-diatom genera were observed in the Little Blackfoot River sample including nine genera of green algae, six genera of blue-green algae, two genera of red algae, and two genera of yellow-green algae. The colonial blue-green N*ostoc*, the filamentous blue-green *Tolypothrix*, the filamentous green alga *Oedogonium*, and the filamentous yellow-green algae *Vaucheria* were common. The relative importance of the blue-greens *Nostoc* and *Tolypothrix,* both taxa capable of fixing nitrogen, suggest that inorganic nitrogen may have been limited relative to phosphorus. This diverse non-diatom algae assemblage suggests relatively high quality, nutrient-rich water with little indication of impairment by metals.

Diatom species richness and Shannon diversity in the Little Blackfoot River was similar to other tributary sites. Of the 62 diatom taxa identified, the epiphytic form *Cocconeis palcentula* was dominant. Other common diatoms included *Epithemia sorex*, *Nitzschia archibaldii, Cocconeis pediculus,* and *Ellerbeckia arenaria*. These diatoms prefer cool, well-oxygenated, alkaline water of moderate conductivity, with low to moderate levels of inorganic nutrients.

Bioassessment scores were mixed in the Little Blackfoot River. Increaser taxa indices suggested high impairment probabilities for sediment 95 percent, metals (65 percent), and nutrients (95 percent) and those scores were 1.2 SD, 1.0 SD, and 1.1 SD above the tributary mean for each, respectively. Those results are also contradicted by surface water monitoring results which generally demonstrate low suspended sediment, metal, and nutrient concentrations in the Little Blackfoot River. In contrast to the high nutrient impairment probability, other indices indicated that the nutrient enrichment was not occurring as the relative abundance of nitrogen-autotroph-sensitive species (27 percent) was 1.5 SD above the tributary mean and the relative abundance of oligosaprobous or ß-mesosaprobous species (84 percent) was 1.3 SD above the tributary mean. Despite predicted impairment, biological integrity in the Little Blackfoot River was rated "good".

4.4.2 Bioassessment Evaluations

Most stressor-specific bioassessment scores had no statistically significant relationship with water quality measurements for the stressors of interest. The general lack of correlation may be due to a high degree of variability in sample results for the periphyton bioassessment values, the water-quality measures, or both and one year of data was insufficient to identify relationships. In addition, the environmental-stressors may occur in combination obscuring the ability of the stressor-specific indices to identify specific impairments from a particular stressor condition.

One exception was that the relative abundance of nitrogen-heterotroph (i.e., organic nitrogen tolerant) species were positively related to both Q3 and annual average organic nitrogen concentrations. The model fit indicated that every increase of 0.1 mg/L in Q3 and annual average organic nitrogen concentrations resulted in expected increases in the relative abundance of nitrogen-heterotroph species of 10 percent (for Q3 concentrations) and 15 percent (for annual average concentrations). These results are compelling and suggest that organic nitrogen enrichment may be directly altering the periphyton assemblage in the CFROU resulting in dominance of nitrogen-heterotroph diatoms at sites most severely enriched by organic nitrogen.

5.0 MACROINVERTEBRATES[57]

5.1 INTRODUCTION

The Clark Fork River, a major tributary of the Columbia River, has been impacted by mining and mineral operations occurring in its headwaters at the confluence of Warm Springs and Silver Bow Creeks in Deer Lodge County, Montana. In the late 1800's and early 1900's these tributaries carried wastes to the Clark Fork from mining, milling and smelting operations in the Butte and Anaconda areas. Wastes included hazardous substances such as arsenic, cadmium, copper, lead, and zinc that contaminate large areas of the Clark Fork floodplain, river sediments and surface water.

Investigations of the character and extent of the contamination on the Clark Fork River began in 1995, subsequent to the EPA designation of a portion of the river from the Warm Springs ponds on Silver Bow Creek to upstream of Milltown Reservoir as a distinct operable unit of the Milltown Reservoir Superfund Site. These investigations showed that natural resources in and around the river were impacted by the release of hazardous substances, prompting the development of an adaptive, comprehensive long-term monitoring plan for evaluating the success of restoration and remediation activities [PBSJ, 2010]. The plan will be implemented over the next decade and includes monitoring techniques and remediation goals for surface water, ground water, in-stream sediment, vegetation, and aquatic biota.

Stream benthic macroinvertebrates are major components of the aquatic biota present in the Clark Fork drainage and thus, play an important role in the comprehensive monitoring plan. The overall goal of the plan for macroinvertebrates "is a reduction of acute and chronic risks to aquatic life as measured by…. benthic macroinvertebrate community integrity…… An absence of impacts to macroinvertebrate organisms will be reflected by a balanced, integrated, and adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the regions [Karr and Dudley, 1981]." Attainment of this goal will be reflected by progressive increases in biological integrity [PBSJ, 2010].

This report describes the analysis of a subset of the benthic macroinvertebrate monitoring program, specifically the samples collected in the Clark Fork drainage in 2017. Prior to 2017, the benthic invertebrate fauna was analyzed using an index developed specifically for the Clark Fork drainage [McGuire, 2010]. This index had been applied over a long course of sampling dating from 1986. However, in 2017 both the indices used to investigate the assemblage and the sampling and laboratory methods (see below) were changed. In 2017, the benthic invertebrate fauna was analyzed with a number of biointegrity metrics which were combined into 4 indices: 1) the MVFP bioassessment index which was developed to evaluate the biological integrity of montane streams [Bollman, 1998]; 2) a predictive model (O/E) that compares the number of organisms collected at

[57] Chapter 5 was prepared by Billie Kerans and Wease Bollman with Rhithron with minor editing and formatting by RESPEC.

a site (O) to the number of organisms expected (E) under undisturbed conditions [Hawkins, 2005; DEQ, 2012b]; 3) the Hilsenhoff Biotic Index [Hilsenhoff, 1987], which has a long history in biomonitoring studies; and 4) a metals tolerance index [McGuire, 2010], which is specifically designed to examine metal pollution. In addition, the taxonomic and functional composition of the benthic fauna was investigated to gain information about probable stressors to water quality and habitat integrity. This information is described in a series of site-specific narratives.

5.2 METHODS

5.2.1 Sampling

Benthic macroinvertebrates were sampled at four Clark Fork River headwater sites, five sites on the mainstem Clark Fork River, and three sites on tributaries of the Clark Fork, on August 30, 2017. Sites are described in Table 5-1. Sampling methods were changed for the 2017 sampling event. In the past, 4 sample replicates were collected at each site using a Hess sampling device. The total area sampled in the 4 replicates was 3.44 m^2 at each location. In 2017, the sampling method was changed to a traveling kick net method that sampled 1 m^2 and only 1 replicate sample was collected at each site. Samples were delivered to Rhithron Associates, Inc. (Rhithron) for processing and identification. In addition, at the request of the RESPEC project manager, data were included for 1 site (Silver Bow Creek at Frontage Road, SS-19) that was sampled on August 29, 2017 using the kick net method.

Table 5-1. Macroinvertebrate sampling sites in the Clark Fork River basin, August 30, 2017.

Site description	Site ID	Co-located USGS gage	Latitude (NAD 83)	Longitude (NAD 83)
Mill-Willow Creek at Frontage Road	MCWC-MWB	NA	46.12649	-112.79876
Mill-Willow Creek Bypass near mouth	MWB-SBC	NA	46.17839	-112.78270
Warm Springs Creek near mouth	WSC-SBC	12323770	46.18041	-112.78592
Silver Bow Creek at Frontage Road[58]	SS-19	NA	45.98520	-112.50770
Silver Bow Creek at Warm Springs	SS-25	12323750	46.18123	-112.77917
Clark Fork River near Galen	CFR-03A	12323800	46.20877	-112.76740
Clark Fork River at Galen Road	CFR-07D	NA	46.23725	-112.75302
Clark Fork River at Gemback Road	CFR-11F	NA	46.26520	-112.74430
Clark Fork River at Williams-Tavenner Bridge	CFR-34	NA	46.39778	-112.74194
Clark Fork River at Turah	CFR-116A	12334550	46.49340	-113.48480
Lost Creek at Frontage Road	LC-7.5	12323850	46.21862	-112.77384
Racetrack Creek at Frontage Road	RTC-1.5	NA	46.28395	-112.74921
Little Blackfoot River at Beck Hill Road	LBR-CFR-02	NA	46.51964	-112.79312

[58] Collected August 29, 2017 as part of the survey of the Streamside Tailings Operable Unit on Silver Bow Creek.

5.2.2 Laboratory Analysis

Laboratory procedures were also changed in 2017. Previously, all Hess samples were completely picked of organisms, following procedures consistent with previous Clark Fork River Biomonitoring projects processed at Rhithron [Bollman, 2010], and the densities of abundant taxa were not estimated, but actual counts were obtained for all organisms [Bollman and Sullivan, 2013; Bollman et al., 2014]. However, in 2017, organisms were subsampled. A subsample of organisms was obtained using methods consistent with Montana Department of Environmental Quality (DEQ) standard procedures [DEQ, 2012b]. The sample was thoroughly mixed in its jar, poured out and evenly spread into the Caton tray. Individual grids were randomly selected, and grid contents were examined under stereoscopic microscopes using 10x-30x magnification (Leica S6E stereoscopic dissecting microscopes). All invertebrates were sorted from each grid and placed in 80 percent ethanol for subsequent identification. Grid selection, examination, and sorting continued until at least 500 (±20 percent) organisms were sorted. The final grid was completely sorted of all organisms. The unsorted sample fraction was retained and stored at the Rhithron laboratory.

Organisms were individually examined by certified taxonomists, using 10x – 80x stereoscopic dissecting scopes (Leica S8E) and identified using appropriate published taxonomic references and keys. For some of the organisms, the taxonomic level to which animals were identified also changed. In the past, organisms were identified to the lowest practical level consistent with previous Clark Fork River Biomonitoring projects [McGuire, 2010]. Identification in 2017 was adjusted to the DEQ's standard effort [DEQ, 2012b]. One key difference between these 2 protocols is that the caddisfly genera *Hydropsyche* and *Ceratopsyche* were differentiated in the McGuire protocol, whereas the DEQ protocol does not recognize the genus *Ceratopsyche* and subsumes it under the genus *Hydropsyche* [Geraci, 2010]. In addition, the McGuire protocol identified these taxa to species level, whereas the DEQ only identified them to the genus (i.e., all taxa in these groups would be reported as the genus *Hydropsyche*). In both protocols, midges and worms were carefully morphotyped using 10x – 80x stereoscopic dissecting microscopes (Leica S8E) and representative specimens were slide mounted and examined at 200x – 1000x magnification under compound microscopes (Olympus BX 51 with Hoffman Contrast and Leica DM1000). Slide mounted organisms were archived at the Rhithron laboratory.

Identification, counts, life stages, and information about the condition of specimens were recorded. Organisms that could not be identified to the taxonomic targets because of immaturity, poor condition, or lack of complete current regionally-applicable published keys were left at appropriate taxonomic levels that were coarser than target levels. To obtain accuracy in richness measures, these organisms were designated as "not unique" if other specimens from the same group could be taken to target levels. Organisms designated as "unique" were those that could be definitively distinguished from other organisms in the sample. Identified organisms were preserved in 80 percent ethanol in labeled vials and archived at the Rhithron laboratory.

5.2.3 Quality Assurance Systems

Quality control procedures for macroinvertebrate sample processing involved checking sorting efficiency on one quality control sample that was randomly selected from the 12 sites. These checks were conducted by trained quality assurance technicians who microscopically re-examined 100 percent of sorted substrate from each quality control sample. Sorting efficiency was evaluated by applying the following calculation:

$$SE = \frac{n_1}{n_1 + n_2} \times 100$$

where: *SE* is the sorting efficiency, expressed as a percentage, n_1 is the total number of specimens in the first sort, and n_2 is the total number of specimens in the second sort.

Quality control procedures for taxonomic determinations of invertebrates involved checking accuracy, precision and enumeration. One sample was randomly selected, and all organisms re-identified and counted by an independent taxonomist. Taxa lists, and enumerations were compared by calculating a Bray-Curtis similarity statistic [Bray and Curtis, 1957] for each selected sample. The percent taxonomic disagreement (PTD) and percent difference in enumeration (PDE) were also calculated [Stribling et al., 2003].

5.2.4 Bioassessment

The bioassessment tools that were used were also changed in 2017. In the past the benthic invertebrate fauna was analyzed using an index developed specifically for the Clark Fork drainage [McGuire, 2010]. The index was divided into 3 parts: a general subset, an organic pollution subset and a metals subset. This index had been applied over a long course of sampling dating from 1986. In 2017 new bioassessment tools were used: the Montana Valley and Foothill Prairies (MVFP) bioassessment index, a predictive model (O/E), the Hilsenhoff Biotic Index (HBI), and the Metals Tolerance Index (MTI). To calculate these tools taxa lists and counts for each sample were constructed. Approximately 72 standard metric expressions of taxonomic, function and habit characters, and tolerance attributes were calculated, using a customized laboratory information system application.

The MVFP bioassessment index [Bollman, 1998] is composed of 6 metrics (Table 5-2). The MVFP index is a quantitative measure which may be useful in assessing progress toward attainment of the general remediation goal of a “balanced, integrated, adaptive community” of aquatic invertebrates, as envisioned by Karr and Dudley [1981]. To arrive at an MVFP index score and impairment classification, each component metric value is calculated, based on the taxonomic, functional, and tolerance attributes of the aquatic invertebrate assemblage, and categorical scores are assigned to each metric. Metric scores are summed for a total score, which is expressed as a percentage of the maximum total score.

Table 5-2. Component metrics and scoring scheme for the aquatic invertebrate-based Montana Valley and Foothill Prairies (MVFP) bioassessment index [Bollman, 1998].

Metric	Metric score			
	3	2	1	0
	Metric values			
Ephemeroptera richness	>5	5 – 4	3 – 2	<2
Plecoptera richness	>3	3 – 2	1	0
Trichoptera richness	>4	4 – 3	2	<2
Number of sensitive taxa	>3	3 – 2	1	0
Percent filterers	0 - 5	5.01 – 10	10.01 – 25	>25
Percent tolerant taxa	0 - 5	5.01 - 10	10.01 - 35	>35

The predictive model (O/E) compares the number of organisms collected at a site (O) to the number of organisms expected (E) under undisturbed conditions [Hawkins, 2005]. Some taxa are excluded from the analysis. Output from the O/E analysis provides a score for each sample. Scoring and impairment classifications were determined using impairment thresholds given in DEQ [2012b]. Sites were classified as unimpaired if the assessment score was above the impairment threshold for that model, and impaired if the score was below the threshold

Indices also included the Hilsenhoff Biotic Index (HBI), with tolerance values and impact threshold modified for Montana fauna [McGuire, 2010], and the Metals Tolerance Index (MTI) that was developed by McGuire [2010] for the Clark Fork River watershed. Table 5-3 shows scoring criteria applied by McGuire for these metrics.

Table 5-3. Hilsenhoff Biotic Index (HBI) and Metals Tolerance Index (MTI): metrics modified and developed by McGuire [2010] for assessing biological integrity in the Clark Fork River basin.

Metric	"no impact" --"severe impact"						
HBI	<4.0	4.0 – 4.5	4.6 – 5.1	5.2 – 5.7	5.8 – 6.3	6.4 – 6.9	>6.9
MTI	<4.0	4.0 – 4.9	5.0 – 5.9	6.0 – 6.9	7.0 – 7.9	8.0 – 8.9	>8.9

5.2.5 Ecological Interpretations

We use narrative interpretations of taxonomic and functional composition of invertebrate assemblages to reveal the probable stressors in the Clark Fork River Operable Unit. Often canonical procedures are used for stressor identification; however, the substantial data required for such procedures (e.g., surveys of habitat, historical and current data related to water quality, land use, point and non-point source influences, soils, hydrology, geology) were not readily available for this study. Instead our narrative interpretations are based on demonstrated associations between assemblage components and habitat and water quality variables gleaned from the published literature, the writer's own research (especially Bollman [1998]) and professional judgment, and the research (especially Wisseman [1996]) and professional judgment of other expert sources.

We use attributes of invertebrate taxa that are well substantiated in diverse literature and that are generally accepted by regional aquatic ecologists as evidence of water quality and instream and reach-scale habitat conditions. The approach to this analysis uses some assemblage attributes that are interpreted as evidence of water quality and other attributes that are interpreted as evidence of habitat integrity. To arrive at impairment classifications, attributes are considered individually, so information is maximized by not relying on a single cumulative score, which may mask stress on the biota. Such an approach also minimizes the possibility of using inappropriate assessment strategies when the biota at a site is atypical of "characteristic" sites in a region. Replicate samples were electronically combined into composited samples for this analysis. Below we describe the invertebrate attributes that were used and their relationships to water quality and habitat conditions.

Mayfly taxa richness, the Hilsenhoff Biotic Index (HBI) value [Hilsenhoff, 1987], the richness and abundance of hemoglobin-bearing taxa, and the richness of sensitive taxa are often used as indicators of water quality. Mayfly taxa richness has been demonstrated to be significantly correlated with chemical measures of dissolved oxygen, pH, and conductivity (e.g., Bollman [1998]; Fore et al. [1996]; Wisseman [1996]). The HBI has a long history of use and validation [Cairns and Pratt, 1993; Smith and Tran, 2010; Johnson and Ringler, 2014]. In Montana foothills, the HBI was demonstrated to be significantly associated with conductivity, pH, water temperature, sediment deposition, and the presence of filamentous algae [Bollman, 1998]. Nutrient enrichment in Montana streams often results in large crops of filamentous algae [Watson, 1988]. Thus, in these samples, when macroinvertebrates associated or dependent on filamentous algae (e.g., Anderson [1976]; LeSage and Harrison [1980]) are abundant, the presence of filamentous algae and nutrient enrichment are also suspected. Sensitive taxa exhibit intolerance to a wide range of stressors (e.g., Hellawell [1986]; Wisseman [1996]; Friedrich [1990]; Barbour et al. [1999]), including nutrient enrichment, acidification, thermal stress, sediment deposition, habitat disruption, and others. These taxa are expected to be present in predictable numbers in functioning montane and foothills streams (e.g., Bollman [1998]).

The richness and abundance of cold stenotherm taxa [Clark, 1997] and calculation of the temperature preference of the macroinvertebrate assemblage [Brandt, 2001] can predict the thermal characteristics of the sampled site. Hemoglobin-bearing taxa are also indicators of warm water temperatures [Walshe, 1947], since dissolved oxygen is directly associated with water temperature; oxygen concentrations can also vary with the degree of nutrient enrichment. Increased temperatures and high nutrient concentrations can, alone or in concert, create conditions favorable to hypoxic sediments, habitats preferred by hemoglobin-bearers.

The absence of invertebrate groups known to be sensitive to metals and the Metals Tolerance Index (MTI) [Bukantis, 1998] are considered signals of possible metals contamination. Metals sensitivity for some groups, especially the heptageniid mayflies, is well-known (e.g., Kiffney and Clements [1994]; Clements [1999]; [2004]; Montz et al. [2010]; Iwasaki et al. [2013]). In the present approach, the absence of these groups in environs where they are typically expected to occur is considered a signal of possible metals contamination, but only when combined with a measure of overall assemblage tolerance of metals. The Metals Tolerance Index ranks taxa according to their sensitivity to metals. Weighting taxa by their abundance in a sample, assemblage tolerance is estimated by averaging the tolerance of all sampled individuals.

Characteristics of the macroinvertebrate assemblages can also reveal the condition of instream and streamside habitats. Stress from sediment is evaluated by caddisfly richness and by "clinger" richness [Kleindl, 1995; Bollman, 1998; Karr and Chu, 1999; Wagenhoff et al., 2012; Leitner et al., 2015]. A newer tool, the Fine Sediment Biotic Index (FSBI) [Relyea et al., 2012] shows promise when applied to the montane and foothills regions. This index and its interpretation are modified in this report, based on the author's professional judgment, to more effectively characterize the Clark Fork River and tributaries in the sampled reaches.

The functional characteristics of macroinvertebrate assemblages are based on the morphology and behaviors associated with feeding and are interpreted in terms of the River Continuum Concept [Vannote et al., 1980] in the narratives. Alterations from predicted patterns in montane and foothills streams may be interpreted as evidence of water quality or habitat disruption. For example, shredders and the microbes they depend on are sensitive to modifications of the riparian zone [Plafkin et al., 1989].

5.2.6 Possible Effects of Changes in Sampling and Laboratory Procedures and Bioassessment Indices

The changes in sampling protocols and laboratory procedures will undoubtedly affect the outcome values for many of the ecological metrics and the indices that use those metrics. Any metrics or indices that contain taxa richness metrics may be affected and the likely direction of that effect would be a lower value. There are several reasons for this. First, the sampling area of the stream bottom is now about 3 times smaller than in the past. This smaller size increases the likelihood that some microhabitats will not be sampled and thus, the organisms that inhabit those areas have the potential to be missing from the sample. This effect is further exacerbated by the change in laboratory procedures to subsampling 500 organisms versus the previous protocol of identifying all the organisms in the sample. Here, animals that are naturally rare in nature have a greater potential to be missed in the subsampling procedure than in the previous protocol. Finally, the changes in the caddisfly taxonomy will directly reduce the number of taxa reported. These taxa are quite common in the Clark Fork River, and thus reductions in taxa richness are to be expected. How these changes would affect other ecological metrics is unpredictable.

The effects of the changes in sampling protocols and procedures on bioassessment will be difficult to determine, because the assessment tools have changed as well. Because the old procedures and assessment tools and the new procedures and new assessment tools were not directly compared (both procedures done at the same time in the same location), it will take time to estimate what these effects will be and how they will influence bioassessment. For example, changes in classification of a site from "unimpaired" to "impaired" may be the result of a "true" reduction in water or habitat quality or could be the result of all the changes in protocols and bioassessment tools.

The effects of the changes may be detected in the narrative interpretations because they rely on individual metrics rather than combinations of individual metrics as the bioassessment indices do. However, the changes will make it difficult to compare results from previous years, where replicated Hess samples and full sample identification were done, to 2017 and future samples. For example, total taxa richness may be lower in 2017 than in was in 2016 or previous years; however, it will be difficult to say whether that difference is the result of the change in procedures or some reduction water or habitat quality.

To begin to examine the possible effects of the changes, we compared the results of selected indices and metrics between 2016 and 2017. We determined the number of sites that scored "lower", "equal to", or "higher" for indices and metrics in 2017 as compared to 2016. Because our expectation was that taxa richness metrics would decline in values, we combined the "equal to" and "higher" categories into one category "= & higher". Given the two categories "lower" and "= & higher" our expectation under random conditions is that scoring "lower" or "= & higher" and should be of equal probability (think a coin toss as to which category a location would be placed. Thus, randomness would place 6 of the 12 locations in the "lower" category. Any bias (defined here as just a trend away from the random expectation of 50 percent scoring lower) could be the result of many factors including changes in water quality and conditions between years, but it could also reflect the effects of the changes in protocols. Disentangling the confounding reasons for the results will require much more data. We present these results as only a first look at the issue and as an aid to determining possible future directions for examination of the issue.

5.3 RESULTS

5.3.1 Quality Assurance Systems

Sample MWB-SBC (Mill-Willow Bypass near mouth) was randomly selected to calculate sorting efficiency and sample SS-25 (Silver Bow Creek at Warm Springs) was selected to calculate Bray-Curtis similarity between original identification and enumeration and subsequent identification and enumeration by an independent taxonomist, percent taxonomic disagreement (PTD), and percent difference in enumeration (PDE). Results were well within quality control standards: sorting efficiency was 98.1 percent, Bray-Curtis similarity was 98.4 percent, PTD was 2.0 percent, and PDE was 0.5 percent. Rhithron's internal quality standards, consistent with industry norms are: for sorting efficiency, at least 95 percent; for Bray-Curtis similarity, at least 95 percent; for PTD, not more than at least 5 percent; and for PDE, not more than 5 percent [Stribling et al., 2003].

5.3.2 Bioassessment

Values for the 6 MVFP aquatic invertebrate metrics are shown in Table 5-4. MVFP scores and associated impairment classifications are given in Table 5-5. Figure 5-1 graphs the 2017 MVFP scores, as percent of maximum possible score, for all sites in the study. Of the 13 sites visited, 10 were rated slightly impaired and 3 were rated moderately impaired by the MVFP. Two headwater sites Mill-Willow Creek Bypass near mouth (MWB-SBC) and Silver Bow Creek at Frontage Road (SS-19) were rated moderately impaired, whereas the other 3 headwater sites were rated slightly impaired. All mainstem sites were rated slightly impaired. The MVFP rated one tributary site (Lost Creek at Frontage Road, LC-7.5) as moderately impaired and the other 2 tributary sites were rated slightly impaired.

The results from the predictive model (O/E) are shown in Figure 5-2 and Table 5-5. All sites failed the test for applicability of the model to the sites, indicating that watershed area exceeds the experience of the model. The predictive model rated all sites as impaired.

In 2017, HBI metric values were elevated relative to the impact threshold for nutrients determined by McGuire [2010] at 9 sites (3 headwater, 4 mainstem, 2 tributaries) (Table 5-5; Figure 5-3). The highest HBI values occurred at sites SS-25 and LC-7.5 where scores were more than 5.0 indicating moderate impairment by organic nutrients [McGuire, 2010]. The scores at all the other sites that scored over the threshold suggested slight impairment by nutrient enrichment. These sites included LBR-CFR-02 that scored especially close to the cutoff (4.01). Headwaters sites MCWC-MWB and SS-19, mainstem sites CFR-07D and CFR-116A, and tributary site RTC-1.5 were below the threshold value. The value for site CFR-116A was below the threshold but rounded up to 4.00.

MTI metric values for 7 sites were elevated relative to the impact threshold for metals determined by McGuire [2010] (Figure 5-4). These sites included 2 headwaters sites (WSC-SBC and SS-25), 4 mainstem sites (CFR-03A, CFR-11F, CFR-34 and CFR-116A) and one tributary site (LC-7.5). All other sites generated MTI values that indicated no impact from metals contamination, according to McGuire's guidance.

Table 5-4. Montana Valley and Foothill Prairies [Bollman, 1998] metric results: Clark Fork River, August 30, 2017.

Site ID	Site Location	Metric					
		Ephemeroptera richness	Plecoptera richness	Trichoptera richness	Number of sensitive taxa	Percent tolerant taxa	Percent filterers
MCWC-MWB	Mill-Willow Creek at Frontage Road	8	3	6	2	20.9	9.0
MWB-SBC	Mill-Willow Creek Bypass near Mouth	3	4	8	1	37.8	18.5
WSC-SBC	Warm Springs Creek near Mouth	5	3	9	1	38.9	4.1
SS-19[59]	Silver Bow Creek at Frontage Road	5	1	6	0	45.1	11.4
SS-25	Silver Bow Creek at Warm Springs	4	1	6	2	27.4	17.6
CFR-03A	Clark Fork River Near Galen	6	2	7	2	44.7	16.5
CFR-07D	Clark Fork River at Galen Road	7	2	9	1	32.9	21.9
CRF-11F	Clark Fork River at Gemback Road	6	2	8	1	30.3	43.1
CFR-34	Clark Fork River at Williams-Tavenner Bridge	6	4	10	0	32.6	39.4
CFR-116A	Clark Fork River at Turah	11	4	10	1	21.2	33.9
LC-7.5	Lost Creek at Frontage Road	5	0	7	0	57.0	22.4
RTC-1.5	Racetrack Creek at Frontage Road	8	6	6	1	17.8	0.4
LBR-CFR-02	Little Blackfoot River at Beck Hill Road	5	4	12	4	14.2	28.0

[59] Collected August 29, 2017 as part of the survey of the Streamside Tailings Operable Unit on Silver Bow Creek.

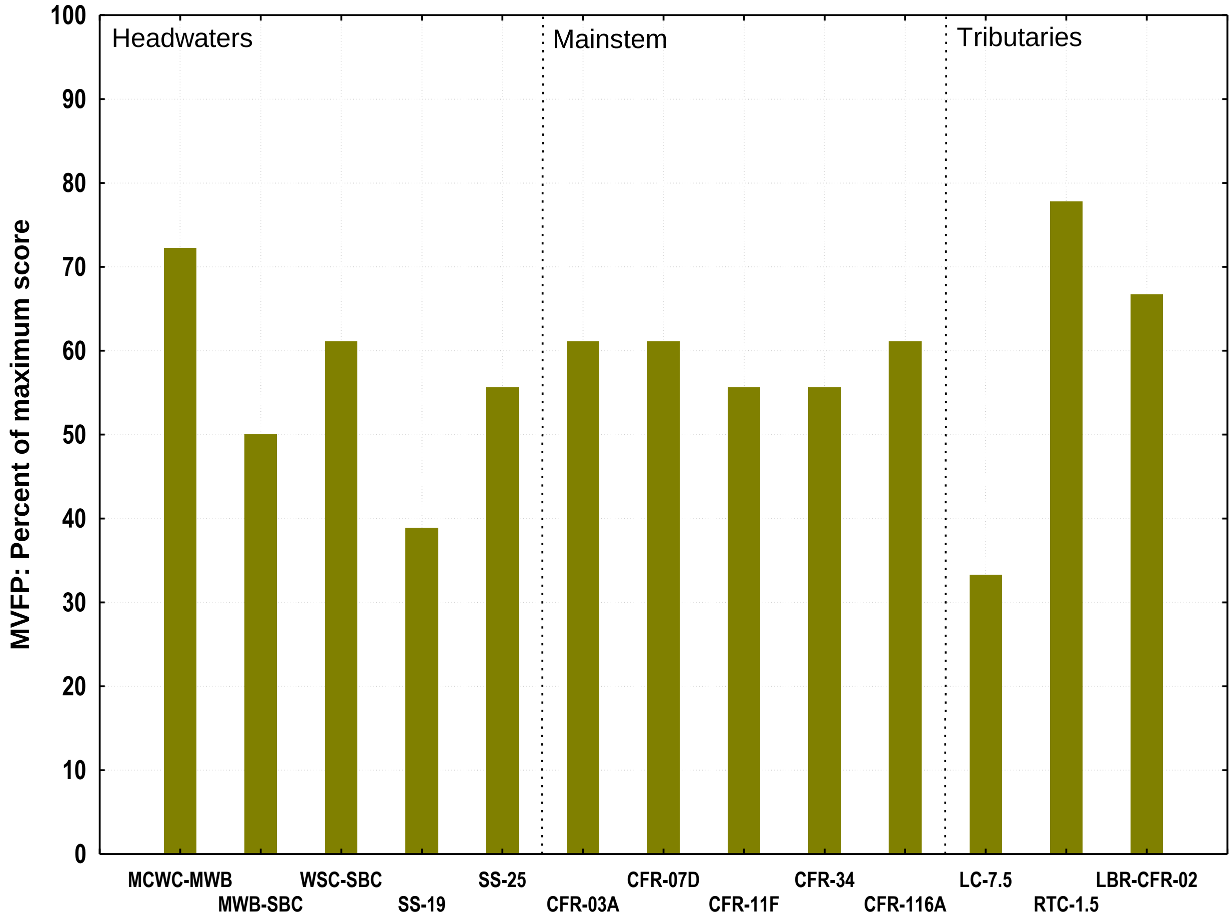

Figure 5-1. MVFP [Bollman, 1998] scores for Clark Fork basin monitoring sites. August 30, 2017.

Table 5-5. Bioassessment scores and values for selected metrics calculated for Clark Fork River sites: MFVP [Bollman, 1998] aquatic invertebrate biointegrity scores, expressed as percent of maximum possible score, with impairment classifications; O/E with impairment classifications (more than 0.80, unimpaired); the Hilsenhoff Biotic Index (HBI) metric values (more than 4.0 impaired); and the metals tolerance index [McGuire, 2010] metric values (more than 4.0 impaired). Clark Fork River, August 30, 2017.

Site ID	Site Location	MVFP score (% of max. score)	MVFP impairment classificatio n	O/E	O/E impairment classification	HBI	MTI
MCWC-MWB	Mill -Willow Creek at Frontage Road	72.2	slight	0.6091	impaired	2.82	2.70
MWB-SBC	Mill-Willow Creek Bypass near mouth	50.0	moderate	0.4404	impaired	4.15	3.97
WSC-SBC	Warm Springs Creek near mouth	61.1	slight	0.5914	impaired	4.44	4.48
SS-19[60]	Silver Bow Creek at Frontage Road	38.9	moderate	0.2291	impaired	3.96	3.28
SS-25	Silver Bow Creek at Warm Springs	55.6	slight	0.4645	impaired	5.17	4.54
CFR-03A	Clark Fork near Galen	61.1	slight	0.2799	impaired	4.70	4.44
CFR-07D	Clark Fork at Galen Road	61.1	slight	0.3546	impaired	3.98	3.74
CFR-11F	Clark Fork at Gemback Road	55.6	slight	0.3892	impaired	4.72	4.36
CFR-34	Clark Fork River at Williams-Tavenner Bridge	55.6	slight	0.3863	impaired	4.65	4.31
CFR-116A	Clark Fork at Turah	61.1	slight	0.4284	impaired	4.00	4.23
LC-7.5	Lost Creek at Frontage Road	33.3	moderate	0.2504	impaired	5.14	4.31
RTC-1.5	Racetrack Creek at Frontage Road	77.8	slight	0.6009	impaired	3.47	3.93
LBR-CFR-02	Little Blackfoot River at Beck Hill Road	66.7	slight	0.3954	impaired	4.01	3.78

[60] Collected August 29, 2017 as part of the survey of the Streamside Tailings Operable Unit on Silver Bow Creek.

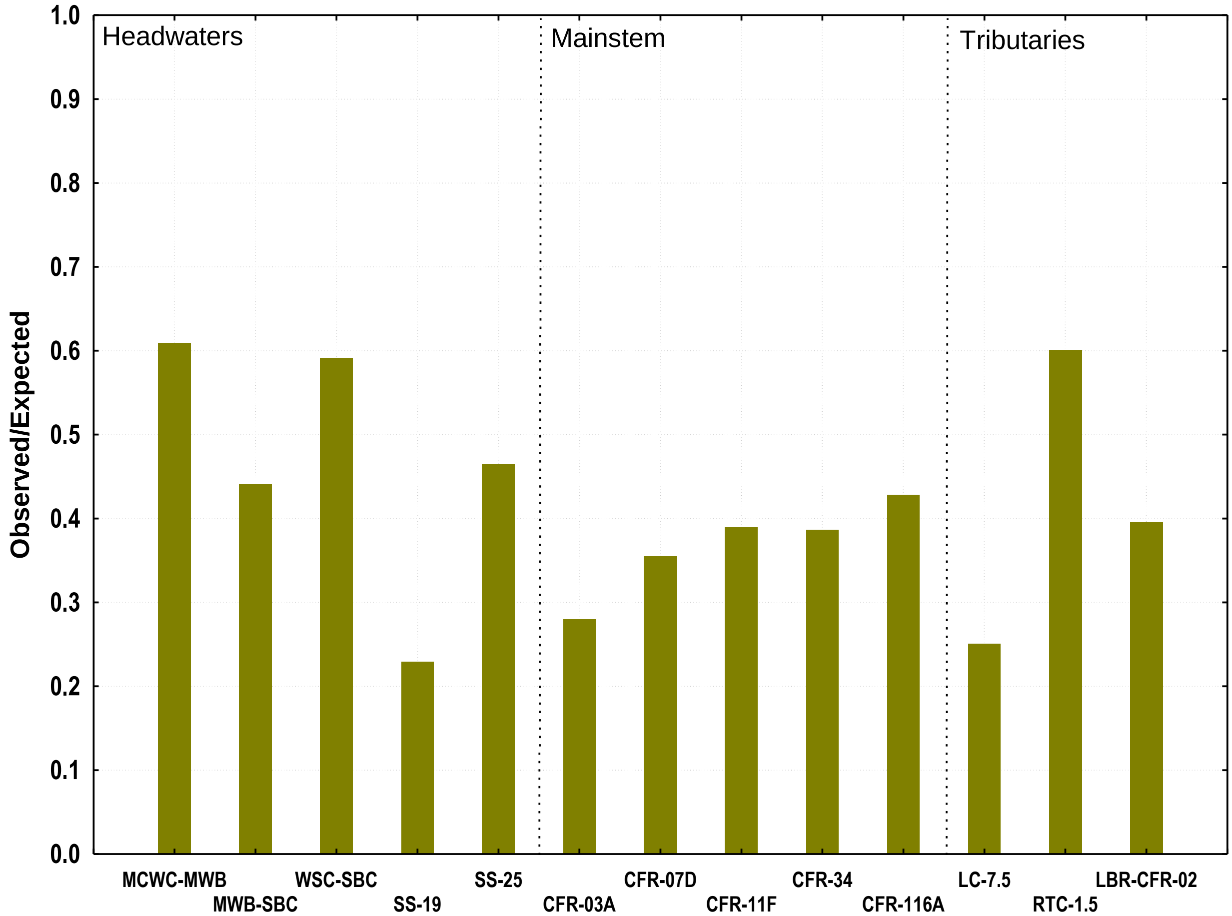

Figure 5-2. O/E predictive model [DEQ, 2012b] results for Clark Fork basin monitoring sites. August 30, 2017.

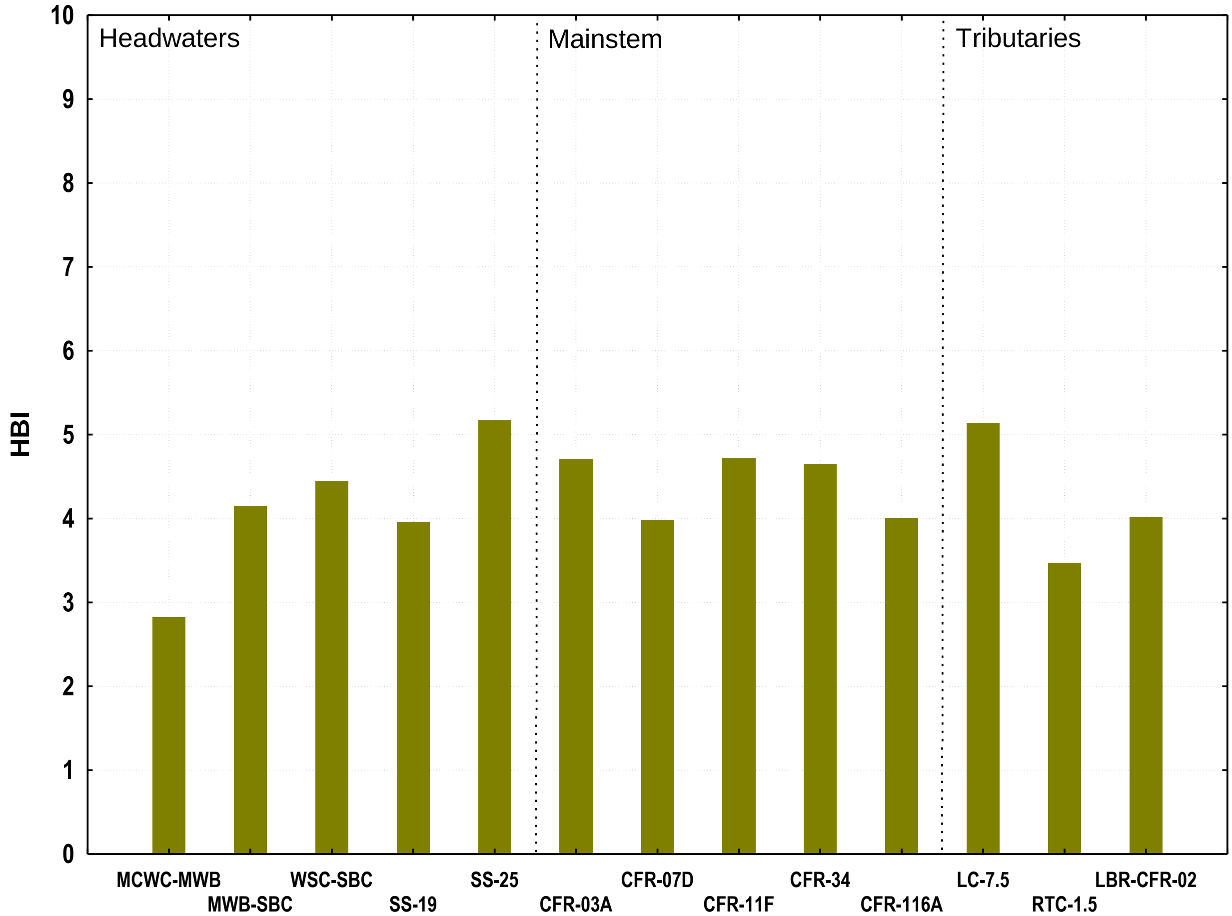

Figure 5-3. Hilsenhoff Biotic Index (HBI) [McGuire, 2010] results for Clark Fork basin monitoring sites. August 30, 2017.

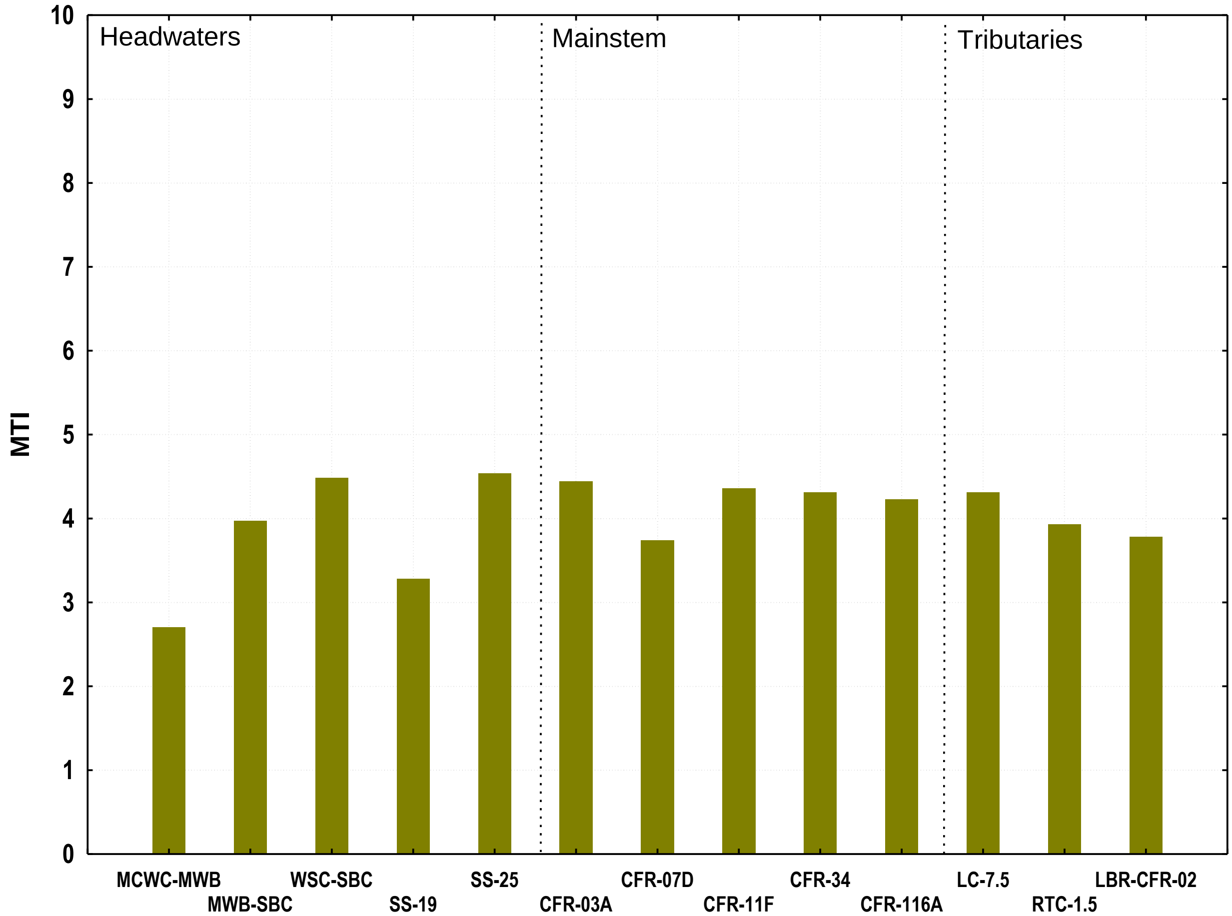

Figure 5-4. Metals Tolerance Index (MTI) [McGuire, 2010] results for Clark Fork basin monitoring sites. August 30, 2017.

5.4 DISCUSSION

5.4.1 Ecological Interpretations

5.4.1.1 Mill-Willow Creek at Frontage Road (MCWC-MWB)

5.4.1.1.1 Water Quality

Within expectations for a low-to-mid-order stream in the Valley and Foothill ecoregion, 8 mayfly taxa were recorded from this sample: 2 baetids *Baetis tricaudatus* complex and *Diphetor hageni*; 3 ephemerellids *Drunella grandis*, *Attenella margarita,* and *Ephemerella excrucians*; 1 heptageniid *Ecdyonurus criddlei*; 1 leptohyphid *Tricorythodes* sp.; and 1 unknown leptophlebiid. Only *B. tricaudatus* complex (5.0 percent) and *Tricorythodes* sp. (2.9 percent) were common. The HBI (2.82) was also within expectations and was the lowest for any site sampled in 2017. However, only 2 pollution-sensitive taxa were collected: the midge *Cricotopus (Nostococladius)* sp. (0.4 percent) and the mayfly *D. grandis* (0.4 percent), neither of which were abundant. Pollution-tolerant organisms (20.9 percent), including the elmid beetle *Optioservus* sp. (14.6 percent, the second most abundant organism in the sample), were a large component of the assemblage. The percentage of collector-filterers (9.0 percent), large abundances of which are often thought to indicate organic pollution, was somewhat elevated. Consequently, although the number of mayfly taxa and the HBI were within expectations, the other characteristics suggested that some slight water quality impairment because of nutrient enrichment cannot be ruled out in this reach. This conclusion was supported by the fact that hemoglobin-bearing organisms (2.1 percent) were common, implying that sediments may have been hypoxic. In addition, annelid worms in the genus *Nais* (2.9 percent) were also common suggesting that filamentous algae were probably common at the site. The presence of substantial filamentous algae is often thought to indicate nutrient enrichment. The MTI (2.70) suggested little possibility of contamination by metals. Indeed, metals-intolerant taxa were present (the heptageniid mayfly *Ecdyonurus criddlei*) and even abundant (the caddisfly *Lepidostoma* sp. (44.3 percent), the dominant organism in the sample).

5.4.1.1.2 Thermal Condition

Only one cold-stenotherm, the midge *C. (Nostococladius)* sp., was collected from this site and it accounted for only a small percentage (0.4 percent) of the sample. The estimated thermal preference of the assemblage was 16.5°C.

5.4.1.1.3 Sediment Deposition

Six caddisfly and 18 “clinger” taxa were found in the sample. The FSBI (2.99) indicated that the assemblage was tolerant of fine sediment. Thus, reduction in macroinvertebrate colonization of the stony stream bottom by the deposition of fine sediment cannot be ruled out in this reach.

5.4.1.1.4 Habitat Diversity and Integrity

Taxa richness (45) was slightly lower than expected. In addition, only 3 stonefly taxa (*Skwala* sp. *Sweltsa* sp. and *Isoperla* sp.) were collected and none of them were abundant: stoneflies accounted for less than 0.6 percent of the sample. Thus, disturbance to instream habitats, channel morphology, streambanks, and riparian function cannot be ruled out here. The presence of 5 semivoltine taxa, including some that were abundant or common (e.g., the elmid beetle, *Optioservus* sp.; the caddisfly *Brachycentrus occidentalis*, 4.4 percent), suggested a fauna that was not substantially influenced by catastrophic dewatering, thermal extremes, or severe sediment pulses. As in 2016, shredders (46.0 percent) dominated the functional composition of the assemblage. Collector-gatherers (22.8 percent), collector-filterers (9.0 percent) and scrapers (16.1 percent) were also abundant. Consequently, allochthonous coarse and fine particulate organic matter and autochthonous algal production were all important to the energy flow in this system.

5.4.1.2 Mill-Willow Bypass near mouth (MWB-SBC)

5.4.1.2.1 Water Quality

Slight water quality impairment through nutrient enrichment seemed to be indicated at this site. Only 3 mayfly taxa were reported: *Baetis rhodani* Gr. (2.1 percent), *Diphetor hageni* (0.2 percent), and *Iswaeon* sp. (0.2 percent). Both the HBI (4.15) and percentage of collector-filterers (18.5 percent) were slightly elevated above expectations for a low-order valley stream. Pollution-tolerant organisms (37.8 percent) were very abundant and included the elmid beetle *Optioservus* sp. (21.9 percent, the dominant organism in the sample). Only 2 specimens of 1 pollution-sensitive taxon (*Cricotopus (Nostococladius)* sp. (0.4 percent)) were reported. Thus, slight impairment due to nutrient enrichment seems to have occurred here. In support of this contention, midges in the genus *Orthocladius* sp. (4.9 percent) were abundant suggesting that filamentous algae were probably common at the site. However, hemoglobin-bearing organisms (0.2 percent) were rare, thus hypoxia in the sediments did not appear to occur here. The fauna provided no evidence for metals contamination as the MTI (3.97) was below the threshold and the metals-intolerant caddisfly *Lepidostoma* sp. (7.7 percent) was abundant.

5.4.1.2.2 Thermal Condition

The estimated thermal preference of the assemblage was 18.1°C. Only 1 cold-stenotherm, the midge *C. (Nostococladius)* sp., was collected from this site and it was rare. Indeed, some warm-water-tolerant taxa were common (e.g., caddisflies *Cheumatopsyche* sp., 2.2 percent).

5.4.1.2.3 Sediment Deposition

The FSBI (3.99) indicated an assemblage that was moderately tolerant of fine sediment. Eight caddisfly taxa and 16 "clingers" were collected in this reach, thus it appears unlikely that the deposition of fine sediment impeded the colonization of invertebrates here.

5.4.1.2.4 Habitat Diversity and Integrity

Some disturbance to instream habitats was likely because only 35 taxa were found in this reach. However, 4 stonefly taxa were collected, including *Skwala* sp. (5.6 percent) which was abundant, suggesting that channel morphology, streambanks, and riparian function were probably intact. Catastrophes like thermal extremes, scouring floods, or dewatering appear unlikely, as 5 long-lived taxa were found, including the elmids *Optioservus* sp. and *Zaitzevia* sp. (11.0 percent), both of which were abundant. Collector-gatherers (29.9 percent) were the most abundant functional feeding group and were followed closely in abundance by the scrapers (24.3 percent). Collector-filterers (18.5 percent) and shredders (12.3 percent) were also abundant. These characteristics of the fauna suggest that fine and coarse particulate organic matter and autochthonous algal production were all important energy pathways in this reach.

5.4.1.3 Warm Springs Creek near mouth (WSC-SBC)

5.4.1.3.1 Water Quality

Like other sites in 2017, some indicators suggested no water quality impairment, whereas others suggested slight impairment at WSC-SBC. Indications of water quality impairment included the collection of only 5 mayfly taxa most of which were uncommon. Only the ubiquitous *Baetis tricaudatus* complex (4.1 percent) and *Rhithrogena* sp. (1.1 percent) were commonly collected. The HBI value (4.44) was also slightly elevated above expectations. The midge *Cricotopus (Nostococladius*) sp., which was common (3.2 percent), was the only pollution-sensitive taxon collected and pollution-tolerant taxa (38.9 percent, primarily the elmid *Optioservus* sp (38.4 percent), the dominant organism in the sample), accounted for a large percentage of the assemblage. Finally, midges in the genus *Orthocladius* (11.6 percent) were abundant and caddisflies in the family Hydroptilidae (0.4 percent) were present. These results suggested abundant filamentous algae that is often associated with nutrient enrichment. Alternatively, there were some indicators that suggested little water quality impairment. No hemoglobin-bearing taxa were reported, and collector-filterers composed only 4.1 percent of the food web. This combination of characteristics suggested that mild water quality impairment, perhaps through nutrient enrichment, cannot be ruled out. The MTI value (4.48) seemed to indicate slight metals contamination; however, the presence of heptageniid mayflies and the abundance of the caddisfly *Lepidostoma* sp. (7.1 percent) make this less likely.

5.4.1.3.2 Thermal Condition

The estimated thermal preference of the site was 15.6°C. *Cricotopus (Nostococladius)* sp. was the only cold-loving taxon reported from this sample.

5.4.1.3.3 Sediment Deposition

Caddisflies were represented by 9 taxa (8 associated with stony stream bottoms) and "clingers" were represented by 18 taxa. The FSBI (3.63) indicated a moderately sediment-tolerant assemblage. Although "clingers" were slightly less diverse than expected, it was unlikely that this site was impacted by fine sediment deposition that would limit the colonization of invertebrates.

5.4.1.3.4 Habitat Diversity and Integrity

Overall taxa richness (39) was below expectations and only 3 stonefly taxa were recorded from this reach. Only *Hesperoperla pacifica* (1.1 percent) was common, and overall abundance of stoneflies was low (less than 2.0 percent of the fauna). Thus, instream habitats may have been monotonous or damaged and channel morphology, streambanks, and riparian function may have been disturbed. However, 5 semivoltine taxa were collected, suggesting that catastrophes like dewatering or thermal stress probably did not interrupt long life cycles. Indeed, the long-lived elmid beetle *Optioservus* sp. (38.4 percent) was the most abundant taxon. Scrapers (39.9 percent) were the most abundant of the feeding groups followed closely by collector-gatherers (24.6 percent) and shredders (19.9 percent). Predators (11.2 percent) and collector-filterers (4.1 percent) occurred in expected proportions. It was clear that autochthonous algal production and allochthonous addition of both coarse and fine particulate organic matter were important to the food web in this reach.

5.4.1.4 Silver Bow Creek at Frontage Road (SS-19)

This site was sampled on August 29, 2017 as part of the Streamside Tailings Operable Unit monitoring on Silver Bow Creek. The sample was collected using a D-frame net and a traveling kick-net method and the sample was subsampled to a 500-organism count. The organism count was increased to 500 (from 300) in 2017. Consequently, the 2017 sample is directly comparable to the samples on the Clark Fork in 2017. However, neither the Clark Fork nor the Silver Bow samples collected prior to 2017 were directly comparable to each other or to the values of the ecological metrics for both sites in 2017.

5.4.1.5 Water Quality

Baetis tricaudatus complex, *Diphetor hageni*, *Iswaeon* sp. *Ephemerella sp.* and *Tricorythodes* sp were the 5 mayfly taxa recorded from this site. Only *Tricorythodes* represented more than 1.0 percent of the assemblage. The biotic index value (3.96) suggested that the assemblage was not impacted by organic pollution. However, pollution-tolerant organisms accounted for 45.1 percent of the sample and no pollution-sensitive taxa were collected. The percentage of filter-feeders (11.4 percent) was above expectations and hemoglobin-bearing taxa (11.0 percent), including the midges *Microtendipes* sp. (5.2 percent) and *Polypedilum* sp. (3.4 percent), were very common in this assemblage. In addition, a few hydroptilid caddisflies often associated with filamentous algae were collected. These findings suggest that water quality impairment through nutrient enrichment cannot be ruled out here and that there was additional stress associated with hypoxic conditions in the sediment. Contamination by metals was not indicated because the MTI (3.28) was lower than the HBI and the caddisfly *Lepidostoma* sp. (16.6 percent) was abundant in the sample.

5.4.1.5.1 Thermal Condition

No cold-stenotherm taxa were recorded from this site. The temperature preference of the assemblage was 17.5ºC.

5.4.1.5.2 Sediment Deposition

Six caddisfly (5 associated with sediments) and 9 "clinger" taxa were found in this sample. The FSBI value (3.25) indicated a sediment-tolerant assemblage. Fine sediment deposition on stony sediments that may negatively influence colonization of macroinvertebrates probably occurred here.

5.4.1.5.3 Habitat Diversity and Integrity

Overall taxa richness (37) was somewhat lower than expected. The stonefly *Skwala* sp. was present with moderate abundance (3.1 percent). Consequently, monotonous or disturbed instream habitats and unstable streambanks, loss of riparian function, or altered channel morphology were suggested. Catastrophic dewatering, thermal extremes, sediment pulses or toxic inputs were probably unlikely because 3 long-lived taxa were collected including the elmid *Optioservus* sp. (9.5 percent). Scrapers (42.3 percent) dominated the functional composition of the assemblage and all other functional groups were well represented. Thus, both fine and coarse particulate matter and instream algal production were the important energy sources in this reach.

5.4.1.6 Silver Bow Creek at Warm Springs (SS-25)

5.4.1.6.1 Water Quality

Water quality appears impaired at SS-25, Silver Bow Creek at Warm Springs. Only 4 mayfly taxa were collected including *Baetis tricaudatus* complex (1.9 percent) and an early instar in the family Ephemerellidae (1.5 percent). The HBI (5.17) was elevated. In fact, this site had the highest HBI value recorded during the 2017 sampling event. Pollution-tolerant organisms (27.4 percent) were extremely abundant, and the only pollution-sensitive taxa found were the midges *Potthastia longimanus* Gr. (0.4 percent) and *P. gaedii* Gr. (0.2 percent) and both were rare. Filtering collectors (16.9 percent) accounted for a higher percentage of the feeding groups than expected, and organisms that are thought to be associated with filamentous algae were common (e.g. *Orthocladius* sp., 2.6 percent) or present (*Hydroptila* sp.). In addition, hemoglobin-bearing animals that are tolerant of low oxygen conditions in the sediments were abundant (6.9 percent: mainly the midge *Microtendipes* sp., 5.6 percent) suggesting that hypoxia in the sediments might have been influential. These 3 conditions are often linked to nutrient enrichment. Most results suggested that nutrient enrichment was at least part of the cause of water quality impairment at this site. Interestingly, flatworms in the subclass Trepaxonemata (23.7 percent, the most abundant organism in the sample) were extremely abundant suggesting that there were groundwater inputs into the reach. The MTI (4.54) indicated slight metals contamination.

5.4.1.6.2 Thermal Condition

No cold-loving taxa were found in this sample. The calculated temperature preference was 16.7°. In addition, several organisms tolerant of warm water temperatures were common or abundant (e.g., the caddisflies *Oecetis sp.* (2.0 percent) and *Cheumatopsyche sp.* (7.6 percent)).

5.4.1.6.3 Sediment Deposition

Only 5 caddisfly taxa associated with stony stream bottoms (6 total taxa) and 14 "clinger" taxa were reported from this site. The FSBI (3.44) also suggested an assemblage that is tolerant of fine sediment. Hence, fine sediments appeared to influence macroinvertebrate colonization of stony substrates in this reach.

5.4.1.6.4 Habitat Diversity and Integrity

Both overall taxa richness (41) and stonefly taxa richness (only 1 specimen of *Sweltsa* sp. was collected) were lower than expected, suggesting limited or monotonous instream habitats and disruption to channel morphology, streambanks, and/or riparian function. Although only 2 long-lived taxa were collected, both were abundant: the elmid beetles *Optioservus* sp. and *Zaitzevia* sp. composed 9.3 percent and 3.5 percent of the assemblage, respectively. Consequently, catastrophes such dewatering, scouring sediment pulses, or thermal extremes were unlikely to have had a major impact on the fauna. Predators (38.5 percent) were the most abundant feeding group. This high percentage was primarily driven by the high abundance of flatworms (23.7 percent) and the tanypod midge *Thienemannimyia* Gr. (8.5 percent). Collector-filterers (17.6 percent), collector-gatherers (16.9 percent), and shredders (15.4 percent) were all similarly abundant suggesting the importance of both fine and coarse particulate organic matter to the food web in this reach. Instream algal production also appeared important to the energy budget as scrapers accounted for 9.4 percent of the assemblage.

5.4.1.7 Clark Fork River near Galen (CFR-03A)

5.4.1.7.1 Water Quality

Six mayfly taxa were reported from the CFR-03A sample including baetids *Baetis tricaudatus* complex (4.8 percent), *Diphetor hageni* (0.4 percent), and *Iswaeon* sp. (1.9 percent); ephemerellids *Drunella spinifera* (0.2 percent) and *Ephemerella* sp. (0.4 percent); and the heptageniid *Rhithrogena* sp. (0.4 percent). Only *Baetis* and *Iswaeon* were common. The HBI (4.69) was above the threshold that indicated organic pollution. Only 2 pollution-sensitive taxa were collected: the midge *Cricotopus (Nostococladius)* sp. (15.5 percent), was abundant, whereas only 1 specimen of the mayfly *D. spinifera* was collected. Pollution-tolerant organisms (44.7 percent) and collector-filterers (16.5 percent) made up larger than expected percentages of the assemblage. The midge *Orthocladius* sp. (3.3 percent), which may have indicated the presence of filamentous algae and thus, nutrient enrichment, was also common. These results suggested that nutrient enrichment occurred at this site. However, a large crop of the blue green alga *Nostoc* sp. and nitrogen limitation may have been indicated because of the abundance of *Cricotopus (Nostococladius)*. Overall, most metrics suggested water quality impairment and nutrient-enriched conditions. Sediments did not appear to be hypoxic as the percentage of hemoglobin-bearing organisms (0.7 percent) was low. Metals contamination may have occurred as the MTI (4.44) was above the threshold, although the metals-intolerant caddisfly *Lepidostoma* sp. (4.3 percent) was common and the heptageniid mayfly *Rhithrogena* sp. was present.

5.4.1.7.2 Thermal Condition

The midge *Cricotopus (Nostococladius)* sp. and the mayfly *Drunella spinifera* were the 2 cold-stenotherms reported from this site. The cold-loving taxa composed 15.7 percent of the assemblage primarily because of the abundance of *Cricotopus (Nostococladius)*. The temperature preference of the assemblage was 15.9°C.

5.4.1.7.3 Sediment Deposition

This site supported 15 "clinger" taxa and 7 caddisfly taxa. Of the caddisfly taxa, 3 were common or abundant including *Hydropsyche* sp. (12.4 percent), *Lepidostoma* sp. (4.3 percent), and *Brachycentrus occidentalis* (3.1 percent). Consequently, it appears that stony substrates were largely free of deposited sediment in 2017. The FSBI value (3.84) indicated a moderately sediment-tolerant fauna.

5.4.1.7.4 Habitat Diversity and Integrity

Instream and reach-scale habitat features appeared to be disturbed at this site. Only 31 taxa were collected, which was the lowest diversity of any site sampled in 2017. In addition, *Isoperla* sp. and *Skwala* sp. were the only stonefly taxa reported and each was only represented by 4 specimens (0.7 percent). Disasters such as dewatering, scouring sediment pulses, or thermal extremes were probably not influential here as 4 long-lived taxa were recorded, including the abundant elmids *Optioservus sp*. (33.3 percent, the most abundant organism in the sample) and *Zaitzevia sp*. (8.1 percent). Scrapers (34.4 percent) were the dominant feeding group. The collector-gatherers (21.3 percent) and collector-filterers (16.5 percent) were also abundant. The abundance of shredders (20.5 percent) was probably an overestimate of the role of riparian inputs to the energy flow in the reach because the *C. (Nostococladius)* sp. does not respond to inputs of coarse particulate matter from streamside. However, even with the midge's percentage removed from the estimate, shredders were still an important feeding guild. Thus, an open canopy and autochthonous algal production within the reach as well as allochthonous fine and coarse particulate organic matter are all important components of the food web.

5.4.1.8 Clark Fork River at Galen Road (CFR-07D)

5.4.1.8.1 Water Quality

The ecological indicators of water quality were varied in terms of their suggestions about water quality impairment. The mayflies were diverse in this reach: 7 taxa were recorded from the sample including 4 baetids, 1 ephemerellid, 1 heptageniid, and 1 leptohyphid. Three of these mayfly taxa were common: the ubiquitous *Baetis tricaudatus* complex (9.9 percent), *Iswaeon* sp. (3.9 percent), and *Diphetor hageni* (2.7 percent). In addition to the diversity of the mayfly assemblage, the HBI (3.98) did not suggest water quality impairment, as it was below the threshold indicating organic pollution. Hemoglobin-bearing organisms (0.9 percent) were also rare. Alternatively, only a few specimens of 1 pollution-sensitive taxon, *Cricotopus (Nostococladius)* sp. (0.5 percent), were collected and the abundances of pollution-tolerant taxa (32.9 percent) and collector-filterers (21.9 percent) were higher than expected for a stream with good water quality. A few specimens of caddisflies associated with filamentous algae were collected (*Hydroptila* sp. 0.5 percent), which also might have indicated nutrient enrichment. Therefore, slight water quality impairment through nutrient enrichment cannot be ruled out at this site. The MTI (3.74) was below the threshold indicating metals contamination and the metals-sensitive caddisfly *Lepidostoma sp.* (11.1 percent) was abundant and heptageniid mayflies were present. These results provide little evidence for contamination by metals in this reach. Finally, flatworms in the subclass Trepaxonemata (3.3 percent) were common here, perhaps indicating the intrusion of groundwater to the reach.

5.4.1.8.2 Thermal Condition

Cricotopus (Nostococladius) sp. was the only cold-loving taxon found in the collection, and it accounted for only a minor percentage of the total abundance of the sample. The temperature preference of the assemblage was 17.6°C and organisms tolerant of warmer water were abundant (e.g., *Helicopsyche sp.* (13.2 percent)).

5.4.1.8.3 Sediment Deposition

Nine caddisfly (8 associated with stony stream bottoms) and 18 "clinger" taxa were collected here suggesting that sediment deposition had not impeded the colonization of stony sediments in this reach. The FSBI value (4.05); however, indicated a moderately sediment-tolerant assemblage.

5.4.1.8.4 Habitat Diversity and Integrity

Overall taxa richness (34) and stonefly taxa richness (2) were lower than expected, suggesting limited instream habitats and disturbed reach-scale habitat features like stream banks and riparian zones. Six semivoltine taxa were found, thus catastrophes such as dewatering, scouring sediment pulses, or thermal extremes probably did not influence the composition of the benthic fauna. Indeed, the long-lived, elmid beetles *Optioservus* sp. (12.2 percent) and *Zaitzevia* sp. (4.5 percent) were abundant. Scrapers (28.3 percent) were the most abundant functional group followed closely in numbers by the collector-filterers (21.9 percent, the caddisfly *Hydropsyche* sp. (14.0 percent) was the most abundant taxon) and collector-gatherers (20.2 percent). Shredders (13.4 percent) were also abundant. Thus, the abundant algal resources and abundant fine and coarse particulate organic matter that were indicated by this distribution of feeding groups suggested the importance of both autochthonous and allochthonous production to the energy balance in this reach.

5.4.1.9 Clark Fork River at Gemback Road (CFR-11F)

5.4.1.9.1 Water Quality

Most ecological indicators suggested that water quality was impaired at site CFR-11F. Six mayfly taxa were recorded in the sample, but only the ubiquitous *Baetis tricaudatus* complex (2.1 percent) and *Diphetor hageni* (1.5 percent) were common. Each of the other taxa accounted for less than 1.0 percent of the fauna. The HBI (4.72) was above the threshold indicating organic pollution may have occurred here. This contention was supported by the relative abundance of collector-filterers (43.1 percent) which was elevated over expectations and by the fact that midges in the genus *Orthocladius* sp. (3.2 percent), indicative of the presence of filamentous algae and thus, nutrient enrichment, were common. Only 1 pollution-sensitive taxon (*Cricotopus* (*Nostococladius*) sp., 0.4 percent) was recorded from this site and pollution-tolerant taxa accounted for 30.3 percent of the assemblage. These characteristics suggested that the fauna of the site have been influenced by nutrient enrichment. Hypoxic sediments were not indicated, however, as hemoglobin-bearing organisms (0.6 percent) were a minor component of the assemblage. The MTI (4.36) indicated mild contamination by metals. However, this contention was not supported by the presence of metals-sensitive heptageniid mayflies and the commonness of the caddisfly *Lepidostoma sp.* (1.9 percent).

5.4.1.9.2 Thermal Condition

Only 1 cold-stenotherm taxon, *Cricotopus (Nostococladius)* sp. was found in the sample from this reach and it was rare. The estimated temperature preference of the assemblage was 16.2°C. In addition, several taxa tolerant of warm water conditions were common (e.g., the caddisflies *Oecetis* sp. (3.9 percent) and *Helicopsyche* sp. (2.6 percent)).

5.4.1.9.3 Sediment Deposition

Sediment deposition probably did not influence colonization of invertebrate taxa to an appreciable extent: the site supported no fewer than 8 caddisfly taxa and 19 “clinger” taxa. However, the FSBI value (4.37) indicated an assemblage that was moderately sediment-tolerant.

5.4.1.9.4 Habitat Diversity and Integrity

Disturbed or monotonous instream habitats may have been indicated as overall taxa richness (35) was low. In addition, only 2 unique stonefly taxa were collected (*Isoperla sp.* (0.4 percent) and *Skwala* sp. (1.7 percent)), perhaps indicating that reach-scale habitat features like stream banks and riparian zones were disturbed. Long-lived taxa were well-represented: 5 such taxa were collected from this site and the elmids *Optioservus sp.* (16.9 percent) and *Zaitzevia sp.* (4.1 percent) were common. Consequently, catastrophic dewatering or thermal extremes did not appear to be influential. Collector-filterers (43.1 percent) dominated the food web primarily because the filtering caddisfly *Hydropsyche* sp. (40.8 percent) was the dominant animal in the sample. Scrapers (24.9 percent) and collector-gatherers (20.4 percent) were also well represented. Unlike all the upstream sites, shredders (3.0 percent) were not abundant. These metrics suggested that periphyton production and fine organic particulates were important to the energy budget of this reach. However, coarse particulate matter, probably in the form of leaves and twigs dropped into the stream from riparian vegetation, was most likely neither deposited nor retained here and thus, contributed little to the food web.

5.4.1.10 Clark Fork River at Williams-Tavenner Bridge (CFR-34)

5.4.1.10.1 Water Quality

Like site CFR-11F, water quality impairment seemed to be impaired through nutrient enrichment here. The HBI (4.65) was slightly elevated above expectations. Only 6 mayfly taxa were recorded; however, the ubiquitous *Baetis tricaudatus* complex (12.3 percent), *Iswaeon* sp.

(4.4 percent), and *Tricorythodes* sp. (3.8 percent) were abundant. Collector-filterers (39.4 percent) dominated the food web, several specimens of at least 2 taxa of hydroptilid caddisflies (1.1 percent) were collected, and hemoglobin-bearing organisms (1.9 percent) were common. These metrics suggest that nutrient enrichment and hypoxia in the sediments occurred in this reach. The fact that pollution-tolerant organisms accounted for 32.6 percent of the assemblage and that no pollution-sensitive taxa were collected also supports the contention that water quality was impaired here. Slight metals contamination was indicated by the MTI (4.31); however, the metals-sensitive caddisfly *Lepidostoma* sp. (3.4 percent) was common.

5.4.1.10.2 Thermal Condition

The calculated temperature preference of the assemblage was 17.1°C. No cold-stenotherm taxa were collected and, like CFR-11F, several warm-water loving taxa were common, including the caddisflies *Oecetis sp.* (4.4 percent), *Cheumatopsyche* sp. (4.9 percent) and *Helicopsyche* sp. (5.9 percent).

5.4.1.10.3 Sediment Deposition

It appeared that fine sediment deposition did not influence the biota in this reach, since 10 caddisfly (8 associated with stony stream bottoms) and 17 “clinger” taxa were sampled here. However, the FSBI value (4.02), indicated a moderately sediment-tolerant assemblage.

5.4.1.10.4 Habitat Diversity and Integrity

Forty-one total taxa were reported from this site indicating instream habitats were perhaps disturbed or monotonous. However, 4 stonefly taxa were collected, including *Isoperla sp.* (2.8 percent) which was common, suggesting that channel morphology, streambanks, and riparian function were probably intact. Six semivoltine species were found in the sample, including the elmid beetle *Optioservus* sp. (4.4 percent), which was common. Dewatering or thermal stress appeared unlikely here. Collector-filterers (39.4 percent) dominated the functional composition in part because of the high abundances of the filtering caddisfly *Hydropsyche* sp. (21.6 percent, the most abundant taxon) and the filtering blackfly *Simulium* sp. (11.6 percent). All other functional groups were well represented, thus, suspended and deposited fine and coarse particulate organic matter and autochthonous algal production were all important in the food web here.

5.4.1.11 Clark Fork River at Turah (CFR-116A)

5.4.1.11.1 Water Quality

Water quality indicators were varied in their suggestion of impairment at this site. Eleven mayfly taxa were supported, and several were common including the baetids *Baetis tricaudatus* complex (5.8 percent) and *Acentrella* sp. (5.4 percent) and the heptageniid *Rhithrogena* sp. (7.8 percent). The HBI value (4.00) indicated an assemblage that was mildly intolerant of organic pollution. There were few hemoglobin-bearing organisms (0.05 percent) in the collection. These characteristics suggest good water quality and well-oxygenated sediments. However, other characteristics suggested impairment due to nutrient enrichment. Collector-filterers (33.9 percent) dominated the functional composition of the assemblage, which is not surprising given that the filtering caddisfly *Hydropsyche* sp. (23.8 percent) was the most abundant organism in the sample. Caddisflies in the family Hydroptilidae (0.2 percent) were present and midges in the genus *Orthocladius* sp. (4.9 percent) that are typically associated with filamentous algae were abundant. These metrics suggest that mild nutrient enrichment cannot be ruled out at this site. In addition, only one pollution-sensitive taxon was reported (*Potthastia gaedii* Gr. 2.4 percent) and pollution-tolerant organisms (21.2 percent) were abundant. The MTI (4.23) indicated slight metals contamination; however, heptageniid mayflies were abundant (8.5 percent).

5.4.1.11.2 Thermal Condition

No cold-loving taxa were recorded from this site. The estimated temperature preference of the assemblage was 16.2°C.

5.4.1.11.3 Sediment Deposition

The site supported at least 10 caddisfly taxa (9 associated with stony sediments) and 25 "clinger" taxa, suggesting that colonization of stony substrates was not inhibited by deposited sediment. The FSBI value (4.63) indicated a moderately sediment-tolerant assemblage.

5.4.1.11.4 Habitat Diversity and Integrity

Instream habitats may have been disrupted or monotonous as only 45 taxa were reported from this sample. However, reach-scale habitat features appeared to be diverse and intact as 4 stonefly taxa were collected including *Isoperla* sp. (2.7 percent) and *Skwala* sp. (4.0 percent). Catastrophes like dewatering or thermal stress probably did not disrupt the life cycles of long-lived organisms, as 7 semivoltine taxa were recorded in this reach and several of them were abundant or common. As mentioned previously, collector-filterers (33.9 percent) dominated the functional mix. Collector-gatherers (29.0 percent) and scrapers (21.1 percent) were also abundant, but shredders (2.2 percent) were scarce. Consequently, important food resources included fine particulate organic matter and algae produced in the reach. Coarse-particulate organic matter appeared to be inconsequential to the food web.

5.4.1.12 Lost Creek at Frontage Road (LC-7.5)

5.4.1.12.1 Water Quality

Water quality seemed to be impaired at this site. Only 5 mayfly taxa were collected and none of them were common: mayflies accounted for only 2.4 percent of the assemblage. The HBI value (5.14) was elevated over expectations and indicated an invertebrate assemblage that was tolerant of organic pollution. Collector-filterers (22.4 percent) and pollution-tolerant taxa (57.0 percent) were very abundant. In addition, no pollution-sensitive taxa were collected. These results suggested that nutrient enrichment was the cause of the water quality impairment here. Caddisflies in the family Hydroptilidae (0.8 percent) were also reported perhaps indicating that filamentous algae occurred at this site, supporting the contention that nutrient enrichment impaired water quality. However, sediments seemed to be well oxygenated as hemoglobin-bearing organisms (0.6 percent) were rare. Interestingly, flatworms in the subclass Trepaxonemata (3.5

percent) were very common thus, groundwater intrusion into this reach seemed likely. The MTI (4.31) indicated slight metals contamination.

5.4.1.12.2 Thermal Condition

No cold-stenotherms were collected from this site. The calculated thermal preference of the fauna was 16.3°C.

5.4.1.12.3 Sediment Deposition

Both the number of caddisfly taxa (7, 6 of which are associated with stony stream bottoms) and "clinger" taxa (14) were lower than expected. These findings suggest that sediment deposition may have compromised stony substrate habitats. The FSBI value (3.38) supported this contention and indicated that the fauna was tolerant of deposited sediment.

5.4.1.12.4 Habitat Diversity and Integrity

Overall taxa richness (42) was somewhat lower than expected and no stoneflies were recorded from this site. Thus, instream habitats may be monotonous or disrupted and reach-scale habitat features like stream banks and riparian zones may be disturbed. Because 5 semivoltine taxa were collected, some of which were abundant (e.g., *Optioservus* sp., 27.2 percent, the most abundant organism in the sample), catastrophes such as dewatering, scouring sediment pulses, or thermal extremes appeared unlikely to have had a major impact on the fauna. All expected functional groups were present: collector-gatherers (36.9 percent) were the most abundant group followed in abundance by scrapers (28.0 percent) and collector-filterers (22.4 percent). Shredders (1.1 percent) were rare. Thus, autochthonous algal production and deposited fine particulate organic matter seemed to be important to the energy flow in this reach. Lack of deposition or retention of coarse particulate organic matter in the reach was also suggested.

5.4.1.13 Racetrack Creek at Frontage Road (RTC-1.5)

5.4.1.13.1 Water Quality

Many ecological indicators suggested that water quality was good at the Racetrack Creek. Eight mayfly taxa were found in the sample and several were common or abundant including *Baetis tricaudatus* complex (9.8 percent), *Drunella grandis* (1.9 percent), *Ephemerella* sp. (2.7 percent) and *Cinygmula* sp. (8.4 percent). The HBI value (3.47) was below expectations. In addition, hemoglobin-bearing organisms (0.4 percent) were uncommon and collector-filterers (0.4 percent) were not a major component of the assemblage. On the other hand, the midge *Orthocladius* sp. (10.3 percent) was abundant and caddisflies in the family Hydroptilidae were present. These taxa are often associated with filamentous algae, which itself is often associated with nutrient enrichment. Only one pollution-sensitive taxon (*D. grandis*) was collected and pollution-tolerant organisms accounted for 17.8 percent of the assemblage. Thus, some mild nutrient enrichment cannot be ruled out here. The MTI (3.93) was below the threshold indicating metals contamination and the metals-intolerant heptageniid mayfly *Cinygmula* sp. was abundant, consequently there was little evidence of metals pollution.

5.4.1.13.2 Thermal Condition

The limnephilid caddisfly *Psychoglypha* sp. (1 specimen, 0.2 percent) was the only cold-stenotherm taxon recorded from this reach. The calculated thermal preference for the assemblage was 14.2°C.

5.4.1.13.3 Sediment Deposition

Twenty-one "clinger" taxa were collected which is within expectations; however, only 6 caddisfly taxa (5 of which are associated with stony stream bottoms) were reported. Thus, limitation of colonization of stony substrates on the stream bottom by fine sediment deposition could not be ruled out here. The FSBI value (4.29) indicated a fauna that was moderately tolerant of fine sediment.

5.4.1.13.4 Habitat Diversity and Integrity

Overall the habitat characteristics of this site appear to be good. Forty-seven total taxa were collected, including 6 stonefly taxa and 5 semivoltine taxa. Of the stonefly taxa, *Skwala* sp. (9.0 percent) was abundant and of the semivoltine species, *Optioservus* sp. (12.1 percent, the most abundant organism in the sample) was abundant. Instream and reach-scale habitats appear intact, and catastrophes like dewatering, thermal extremes or scouring sediment pulses do not appear to have interrupted the life cycles of long-lived organisms. The functional composition of the assemblage was dominated by collector-gatherers (36.7 percent) indicating the importance of deposited fine particulate organic matter to the energy flow in this reach. In addition, scrapers (24.7 percent) were abundant, indicating the importance of algal production to the food web. Predators (23.5 percent) were also abundant, and over half of these were predatory stoneflies (13.8 percent). All other functional groups were well represented except for collector-filterers.

5.4.1.14 Little Blackfoot River at Beck Hill Road (LBR-CFR-02)

5.4.1.14.1 Water Quality

Like other sites in 2017, some indicators suggested good water quality, whereas others suggested some impairment at LBR-CFR-02. Only 5 mayfly taxa were counted in the sample and none of them were abundant. Collector-filterers (28.0 percent) were abundant and hemoglobin-bearing organisms (1.3 percent) were common. In addition, the midge *Orthocladius* sp. (3.6 percent) and the caddisfly *Hydroptila* sp., taxa typically associated with filamentous algae and nutrient enrichment, were common and present, respectively. The percentage of pollution-tolerant animals (14.2 percent) was slightly higher than expected. However, 4 pollution-sensitive taxa were recorded: *Cricotopus* (*Nostococladius*) sp. (9.2 percent) was abundant and *D. spinifera* (0.2 percent), *Potthastia longimanus* Gr. (0.2 percent), and *Potthastia gaedii* Gr. (0.2 percent) were rare. Also, the HBI (4.01) was only slightly elevated. Thus, the possibility of some mild nutrient enrichment and hypoxia in the sediments cannot be ruled out here. But abundant *Cricotopus (Nostococladius)* sp. suggested a large crop of the blue green alga *Nostoc* sp. and nitrogen limitation. There was no evidence of metals contamination as the MTI was 3.78. Also, the metals sensitive caddisfly *Lepidostoma* sp. (12.3 percent) was abundant.

5.4.1.14.2 Thermal Condition

The mayfly *Drunella spinifera* and the midge *Cricotopus (Nostococladius)* sp. were the only cold stenotherms reported from this site and only *Cricotopus (Nostococladius)* was abundant. The calculated temperature preference of the assemblage was 18.9°C.

5.4.1.14.3 Sediment Deposition

Twelve caddisfly (11 associated with stony stream bottoms) and 20 “clinger” taxa were collected at this site suggesting that the deposition of fine sediments did not influence the colonization of stony substrates in this reach. The FSBI (4.57) indicates a fauna that was moderately tolerant of fine sediment.

5.4.1.14.4 Habitat Diversity and Integrity

Overall taxa richness (49) was only slightly lower than expected suggesting diverse and intact instream habitats. However, only 4 stonefly taxa were collected, and they were all uncommon suggesting that reach-scale habitat features were disrupted. In addition, 6 long-lived taxa were counted, and the elmids *Optioservus sp*. (4.7 percent) and *Zaitzevia* sp. (3.1 percent) were common: year-round surface flow and absence of events that would interrupt long life cycles were indicated. Collector-filters (28.0 percent), collector-gatherers (20.7 percent) and shredders (22.6 percent) were all very abundant suggesting the importance of allochthonous fine and coarse particulate matter to the food web. Scrapers (11.2 percent) were also abundant indicating that autochthonous algal production was important to the energy budget as well.

5.4.2 Possible Effects of Changes to Sampling and Laboratory Procedures

Table 5-7 shows the comparison of the results of selected indices and metrics between 2016 and 2017. Any bias (defined here as just a trend away from the random expectation of 50 percent scoring “= & higher” and 50 percent scoring “lower”) could be the result of many factors including changes in water quality and conditions between years, but it could also reflect the effects of the changes in protocols. Disentangling the confounding reasons for the results will require much more data. We present these results as only a first look at the issue and as an aid to determining possible future directions for examination of the issue.

Our expectations were that the changes in protocols would cause a decrease in the values of taxa richness metrics. This appeared to be the case for total taxa, caddisfly taxa, semivoltine taxa, and clinger taxa. Mayfly and stonefly taxa were close to the expectation of randomness. Interestingly, the MVFP and O/E indices did not reflect the trend of lower taxa richnesses by exhibiting lower scores in 2017 than in 2016: scores appeared to be higher in 2017 than in 2016. The HBI and MTI appeared to reflect the expectation of randomness.

These results reflect the complexity of the issue of disentangling the effects of changing protocols from actual changes in water quality.

5.5 CONCLUSIONS

The MVFP scored all 13 sites as either slightly or moderately impaired. The O/E index scored all sites as impaired. The O/E may not be an appropriate evaluation tool for these sites, since reference conditions for streams with large watershed area have not been established for the 2012 model.

The HBI indicated that organic pollution was a potential cause of impairment at 8 sites. Only Mill -Willow Creek at Frontage Road (MCWC-MWB), Silver Bow Creek at Frontage Road (SS-19), Clark Fork at Galen Road (CFR-07D), Clark Fork at Turah (CFR-116A), and Racetrack Creek at Frontage Road (RTC-1.5) scored below the 4.00 threshold.

The MTI indicated that contamination by metals occurred at 7 sites. Only Mill -Willow Creek at Frontage Road (MCWC-MWB), Mill-Willow Creek Bypass near mouth (MWB-SBC), Silver Bow Creek at Frontage Road (SS-19), Clark Fork at Galen Road (CFR-07D), Racetrack Creek at Frontage Road (RTC-1.5), and Little Blackfoot River at Beck Hill Road (LBR-CFR-02) scored below the 4.00 threshold.

Table 5-6 summarizes the probable stressors suggested by the taxonomic and functional composition of macroinvertebrate assemblages at each site.

Table 5-6. Clark Fork River basin sites and probable stressors as suggested by the composition of macroinvertebrate assemblages, as described in narrative interpretations. Clark Fork River basin, August 30, 2017.

Site name	Site ID	Nutrient and/or organic pollution	Metals	Sediment deposition	Habitat instability
Mill -Willow Creek at Frontage Road	MCWC-MWB	?		?	+
Mill-Willow Creek Bypass near mouth	MWB-SBC	+			+
Warm Springs Creek near mouth	WSC-SBC	?	?		+
Silver Bow Creek at Frontage Road[61]	SS-19	?		+	+
Silver Bow Creek at Warm Springs	SS-25	+	+	+	+
Clark Fork River near Galen at Perkins Lane	CFR-03A	+	?		+
Clark Fork River at Galen Road	CFR-07D	?			+
Clark Fork River at Gemback Road	CFR-11F	+	?		+
Clark Fork River at Williams-Tavenner Bridge	CFR-34	+	?		+
Clark Fork River at Turah	CFR-116A	?	?		+
Lost Creek at Frontage Road	LC-7.5	+	+	+	+
Racetrack Creek at Frontage Road	RTC-1.5	?		?	
Little Blackfoot River at Beck Hill Road	LBR-CFR-2	?			+

+	Composition of the assemblage suggests stress.
?	Evidence from the assemblage was contradictory or inconclusive.

[61] Collected August 29, 2017 as part of the survey of the Streamside Tailings Operable Unit on Silver Bow Creek.

Table 5-7. Clark Fork River basin sites and comparisons of selected indices and taxa richness metrics between 2016 and 2017. Clark Fork River Basin, August 30, 2017.

Site Name	Site ID	Indices				Selected Taxa Richness Metrics					
		MVFP[62]	O/E[62]	HBI[63]	MTI[63]	Total Taxa	Mayfly Taxa	Stonefly taxa	Caddisfly taxa	Semivoltine taxa	Clinger taxa
Mill -Willow Creek at Frontage Road	MCWC -MWB	↑	↑	↓	↓	↓	↑	=	↓	↓	↓
Mill-Willow Creek Bypass near mouth	MWB-SBC	↓	↑	↓	↓	↓	↓	↑	↓	↓	↓
Warm Springs Creek near mouth	WSC-SBC	=	↑	↑	↑	↓	↓	↓	↓	↓	↓
Silver Bow Creek at Warm Springs	SS-25	↑	↑	↓	↓	↓	↑	=	↓	↓	↓
Clark Fork near Galen	CFR-03A	↑	=	↑	↑	↓	↓	↓	↓	↓	↓
Clark Fork at Galen Road	CFR-07D	↑	↑	↑	↑	↓	↓	=	↓	=	↓
Clark Fork at Gemback Road	CFR-11F	↑	↑	↑	↑	↓	↓	=	↓	↓	↓
Clark Fork River at Williams-Tavenner Bridge	CFR-34	↑	↑	↑	↑	↓	↓	=	↓	=	↓
Clark Fork at Turah	CFR-116A	↓	↑	↓	↓	↓	↑	↓	↓	↓	↓
Lost Creek at Frontage Road	LC-7.5	↓	↓	↓	↓	↓	=	↓	=	=	↑
Racetrack Creek at Frontage Road	RTC-1.5	↑	↑	↓	↓	↓	↑	↓	↓	↓	↓
Little Blackfoot River at Beck Hill Road	LBR-CFR-02	↑	↑	↓	↓	↓	↓	↓	↓	↓	↓
Number scoring lower/total number		3/12	1/12	7/12	7/12	12/12	7/12	6/12	11/12	9/12	11/12

↑ The score of that metric or index was higher in 2017 than 2016.

↓ The score of that metric or index was lower in 2017 than 2016.

= The score of that metric or index was the same in 2016 and 2017.

[62] Higher number suggests better conditions.

[63] Lower number suggests better conditions.

6.0 FISH[64]

6.1 INTRODUCTION

The upper Clark Fork River was subject to extensive mining and mineral processing activities during the late 19th and early 20th centuries. Metal contamination from these activities have reduced habitat quality and altered the fishery in the upper Clark Fork River. Fishery changes include reduced trout numbers and changes in species composition. Because of these negative impacts, angling use of the Clark Fork River is lower than other streams in western Montana. Remediation and restoration efforts are ongoing and aim to mitigate historical mining and smelting damage to natural resources in the upper Clark Fork River basin.

The primary goal for aquatic restoration in mainstem Silver Bow Creek and the upper Clark Fork River is to restore the fishery and angling resources to levels of similar rivers not impacted by mining contamination [Saffel et al., 2018; NRDP, 2012]. Remediation and restoration in the mainstem are being completed cooperatively by the Montana Department of Environmental Quality (DEQ) and the Natural Resource Damage Program (NRDP).

Monitoring such an extensive restoration effort requires an extensive monitoring program. In the past, fisheries data collection was conduced sporadically in the upper Clark Fork River basin. In 1999, Montana Fish, Wildlife and Parks (MFWP) biologists established long term monitoring sections that are representative of the upper Clark Fork River. MFWP has completed population estimates in these reaches each of the subsequent years. These mainstem population surveys provide a dataset that can be used to evaluate the mainstem Clark Fork River fishery before, during, and after restoration and remediation actions.

Freshwater salmonids migrate between different habitats to complete life history requirements. Therefore, enhancing the upper Clark Fork River fishery requires not only improving mainstem habitats, but also ensuring that fish in the mainstem have access to quality habitats in tributaries as well. Multiple tributaries have been identified as priorities for restoration in the upper Clark Fork River basin [Saffel et al., 2018]. A variety of tributary restoration projects are underway, and more are planned for the coming decades [NRDP, 2016]. The goals of tributary restoration are to improve trout recruitment to the mainstem, provide additional angling opportunities to offset lost opportunity in the mainstem, and increase populations of native fishes. The effectiveness of tributary projects and the contribution of tributary restoration to the recovery of the mainstem fishery will be evaluated through fisheries monitoring. Detecting responses of tributary fish populations requires that fish surveys be

[64] Chapter 6 was prepared by Nathan Cook, Tracy Elam, Brad Liermann, Jason Lindstrom, and Pat Saffel of Montana Fish, Wildlife, and Parks with minor editing and formatting by RESPEC.

comprehensive, both temporally and spatially, in order to differentiate the effects of restoration from natural variations in abundance.

Information on trout abundance is valuable, but this information does not explain the mechanism by which tributary restoration may benefit the mainstem fishery. It is also important to understand all of the critical factors limiting trout recruitment in the mainstem. Knowing the location of important spawning and rearing habitats used by a salmonid population is critical to managing and restoring these populations. Telemetry studies indicated locations of brown trout spawning activity in both the mainstem upper Clark Fork River and tributary habitats [Mayfield, 2013]. However, just because a fish is in an area during spawning season does not guarantee that the fish will successfully spawn or that the resulting offspring will survive. Successful spawning and survival of juveniles (referred to as recruitment) will largely determine the abundance of adult trout in later years. Determining sources of successful recruitment requires that individual fish be assigned to these sources through genetics or other techniques such as hard part (bony tissue) microchemistry. Microchemical techniques such as laser ablation inductively coupled plasma mass spectrometry (LA-ICPMS) can determine the chemical signatures of bony structures such as fins or otoliths as those structures incorporate chemical changes in the fish's environment over its lifetime. More specifically, this technique has been used in several studies to determine a fish's natal stream and to identify key migrations that occurred during a fish's life [Pracheil et al., 2014].

One of the primary microchemistry markers used to assess freshwater fish migrations is strontium (Sr). Otolith strontium isotope (^{87}Sr:^{86}Sr) ratios and Sr/Ca ratios have been found to discriminate between habitats of interest because these chemical markers are directly related to the chemistry of the water in which fish are living [Clarke et al., 2007]. Like Sr and Ca, barium (Ba) is also an alkaline earth metal, a chemical group that is readily incorporated into the aragonite (crystallized $CaCO_3$) matrix that make up otoliths [Campana, 1999]. Thus, these alkaline earth metals show the most promise for tracing life history and movements by sampling different regions of otoliths [Wells et al., 2003; Gibson-Reinemer et al., 2008].

Caged fish studies have been used to monitor baseline survival and metals concentrations of juvenile brown trout (*Salmo trutta)* prior to restoration [Cook et al., 2015]. Remediation and restoration activities are underway on the upper Clark Fork River that will reduce metal contamination. By reducing metals inputs, clean-up activities will have long term benefits to the upper Clark Fork River fishery. However, these activities involve removing vegetation and disturbing stream banks. These disturbances have the potential to temporarily increase inputs of metal laden sediments into the Clark Fork River. Current caged fish studies have shifted focus from providing baseline data to monitoring for potential acute affects of construction related disturbances.

Results of upper Clark Fork River caged fish studies showed that fish that resided in more contaminated reaches of the upper Clark Fork River accumulated more copper and zinc compared to tributaries [Cook et al., 2014]. Studies of metals concentrations in tissues of wild brown trout from contaminated reaches of the upper Clark Fork River have shown elevated levels of copper, cadmium, lead, and arsenic compared to reference sites [Farag et al., 1995]. Elevated concentrations of these metals have been linked to oxidative stress [Farag et al., 1994], reduced growth and condition, and lower reproductive success [Couture and Pyle, 2012]. Caged fish studies have the benefit of fixing the location in which a fish lives. Knowing a fish's location over time makes it easier to determine exposure to environmental conditions. However, free-ranging wild fish must also be studied, because these are the fish that will ultimately benefit from metals cleanup efforts. In the upper Clark Fork River wild fish tissues have been recently sampled for mercury for human health concerns [T. Selch, MFWP, *personal communication*], but ecological evaluations of impact of copper, zinc, lead, cadmium, and arsenic have not been conducted on wild fish in decades. So, current data tissue burden data are needed to provide background for ongoing remediation.

6.1.1 Objectives

To gather critical fisheries data in the upper Clark Fork River basin, an intensive monitoring program was initiated in 2015. This program has the following objectives:

1. Describe trout population abundances and species composition of fish communities in the upper Clark Fork River, Silver Bow Creek, and priority tributaries.
2. Investigate the natal origins and sources of recruitment for brown trout in the mainstem Clark Fork River using otolith microchemistry.
3. Gather additional data on age, growth, condition, and mortality from brown trout otoliths.
4. Monitor mortality and metals uptake of fish in cages upstream and downstream of reclamation sites in the upper Clark Fork River.

6.1.2 Study Area

Silver Bow Creek originates from Blacktail Creek which flows from the continental divide north-east to the town of Butte. Silver Bow Creek flows through the town of Butte, downstream of which it is joined by two major tributaries, Browns Gulch and German Gulch. A fish barrier was constructed downstream of Durant Canyon to prevent non-native brown trout and rainbow trout (*Oncorhynchus mykiss)* from downstream of the barrier from negatively interacting with the genetically pure westslope cutthroat trout *(Oncorhynchus clarkii lewisi)* upstream of the barrier. Silver Bow Creek flows into a series of set of settling ponds near Warm Springs. These ponds were constructed to trap sediments contaminated with mining waste and reduce the toxicity of metals such as copper and zinc. Rem activities, including extensive tailings removal, have been completed on Silver Bow Creek between Butte and Warm Springs.

Warm Springs Creek joins Silver Bow Creek downstream of the Warm Springs Ponds to become the Clark Fork River. The upper Clark Fork River is often divided into three reaches based on tributary confluences [Hornberger et al., 2009; Mayfield, 2013]. Reach A is the 63 km of the upper Clark Fork River from the confluences of Warm Springs Creek to the Little Blackfoot River. Reach B is 43 km long and is bounded by the Little Blackfoot River and Flint Creek. Reach

C is 84 km long and runs from Flint Creek to the Blackfoot River. Although Reach C is bounded on the downstream end by the Blackfoot River, this report focuses on monitoring activities that occur primarily upstream of Rock Creek.

Tributaries of the upper Warm Springs Drainage originate from the south slope of the Flint Creek Range and the north slope of the Anaconda Range. Meyers Dam, located 5.5 km upstream of Anaconda, is a barrier to fish migrating upstream in Warm Springs Creek. Tributaries of interest in this study were the West Fork of Warm Springs, Storm Lake, Twin Lakes, Foster, and Barker creeks.

Lost and Racetrack Creeks flow east from the Flint Creek Range and join the Clark Fork River between the towns of Warm Springs and Deer Lodge. Cottonwood Creek flows out of the Boulder Mountains where it joins the Clark Fork River on the east side of Deer Lodge. The lower reaches of Lost, Racetrack, and Cottonwood creeks are impacted by dewatering during the irrigation season.

The Little Blackfoot River flows into the Clark Fork River near Garrison. The Little Blackfoot River adds significant flow to the Clark Fork River and reduces concentrations of suspended sediment and metal contaminants through dilution [Sando et al., 2014]. Downstream of the Little Blackfoot River near the town of Garrison, Warm Springs Creek (different than the Warm Springs Creek near Anaconda) and Gold Creek enter the Clark Fork.

Flint Creek starts at the outflow of Georgetown Lake. It is joined by Boulder Creek near the town of Maxville. The lower reaches of Flint Creek are heavily dewatered during the irrigation season.

Harvey Creek is a small tributary that originates in the John Long Mountain Range. A barrier near the mouth of Harvey Creek isolates native westslope cutthroat trout and bull trout (*Salvelinus confluentus)*, but also prevents nonnative species present in the Clark Fork River from moving upstream and interacting with the native species.

Rock Creek is a major tributary to the upper Clark Fork River and supports a robust brown trout fishery in the lower reaches and populations of westslope cutthroat trout and bull trout in upper reaches and tributary streams. Rainbow trout are also present in the Rock Creek watershed as well as mountain whitefish (*Prosopium williamsoni)*, longnose sucker (*Catostomus catostomus)*, largescale sucker (*Catostomus commersonii),* northern pikeminnow *(Ptychocheilus oregonensis),* and sculpins (*Cottus spp.)*.

6.2 METHODS

6.2.1 Population Monitoring

6.2.1.1 Mainstem

Trout population estimates were conducted in spring 2017 at six established sections on the Clark Fork River. These sections are sampled annually by MFWP and are referred to as Bearmouth, Morse Ranch, Phosphate, Williams Tavenner, Below Sager Lane, and pH Shack. A population estimate was also conducted from the bottom of pH Shack to Perkins Lane. This is an electrofishing section that has been sampled in 2009-2012 and again from 2015-present. Fish were collected using aluminum drift boats with a mounted electrofishing unit and two front boom anodes and one netter. Estimates were made using two mark runs and two recapture runs. Recapture runs were completed roughly one week after marking runs. All captured trout were identified to species, weighed (g), measured (mm), and marked with a small fin clip. A subsample of fish was collected on the final recapture runs for otoliths and tissue metal samples (see below for specific methods). Population estimates for fish ≥175 mm (~7 in) were generated using the Chapman modification [Chapman, 1951] of the Petersen method provided in MFWP's Fisheries Information System. Estimates were calculated for trout species that had a minimum of four marked fish that were recaptured.

6.2.1.2 Tributaries

Population estimates were conducted in 18 tributaries in the upper Clark Fork River basin identified as high priority in Saffel et al. [2018] (**Figure 6-1**). Population estimates were generated either by mark-recapture or depletion methods. Mark-recapture estimates consisting of one mark and one recapture run were conducted on larger waters (Flint Creek, lower Little Blackfoot River, and lower Warm Springs Creek). Two- to four-pass depletion estimates [Zippin, 1958] were conducted at other sections. Fish were collected at most tributary sections using one or two backpack electrofishing units. In larger streams, a barge mounted electrofishing unit was used to collect fish. Descriptions of sampling methods, section lengths, and locations of sampling sections can be found in Appendix J.

6.2.1.3 Hard Part Microchemistry

In fall of 2015, water samples were collected at 16 sites throughout the upper Clark Fork River basin to verify that there was sufficient variation in geochemical markers to proceed with a full otolith microchemistry study (**Figure 6-2**). Mainstem sites were located near the downstream boundaries of Reaches A, B, and C. An additional mainstem site was located upstream of the confluence of Racetrack Creek. Tributary water collection sites were located near tributary mouths. In Rock Creek, Flint Creek, Warm Springs Creek, and the Little Blackfoot River, additional water samples were collected approximately halfway between the mouth and the headwaters to provide additional spatial resolution of chemical markers. Water samples were extracted by pumping 50 ml of stream water through a 0.2 µm syringe filter into an acid washed vial. Water samples were preserved by adding a nitric acid solution and refrigerated until they were shipped to the Woods Hole Oceanic Institute for analyses. Water samples were analyzed for elemental ratios (i.e., Sr:Ca, Ba:Ca) using a Thermo Scientific ELEMENT 2, rapid scanning, magnetic sector, single collector inductively-coupled plasma mass spectrometer (ICPMS). Strontium isotope ratios (^{87}Sr:^{86}Sr) were determined by a Thermo Scientific NEPTUNE, large format, magnetic sector, multicollector ICPMS.

Sagittal otoliths from brown trout in the upper Clark Fork River were collected in 2016 and 2017 from the mainstem, two tributaries, and Big Springs Trout Hatchery for microchemical analyses (**Figure 6-2**). Whole fish were collected by electrofishing and individually tagged and frozen. Fish were partially thawed at a later date and otoliths were extracted using non-metallic forceps. Most fish were collected during annual population surveys although some additional sampling was needed to reach desired sample sizes.

Between 2016 and 2017, 320 brown trout were collected from the mainstem Clark Fork River divided roughly between reaches A (n = 120), B (n = 100), and C (n = 100) (**Table 6-1**). There are three annual population survey sections in reach A, two in reach B, and one in reach C. Fish were collected from an additional river section between Beavertail and Rock Creek to add more otoliths to the reach C sample. When possible, we collected fish from five length categories at each mainstem sampling section. These length categories were: not more than 175 mm, 175-249 mm, 250-324 mm, 325-399 mm, and 400+ mm, roughly corresponding to age <2-, 3-, 4-, 5-, and 6+ year-old fish. The number of fish collected in each length category was dependent on the number of sampling sections within reaches A, B, and C (**Table 6-1**). This sampling scheme was designed to provide roughly equal sample sizes for the different reaches of the upper Clark Fork River.

In 2016, 86 juvenile brown trout otoliths were collected from 16 different sites in 11 tributaries of the upper Clark Fork River. Tributaries sampled in 2016 included Warm Springs Creek, Lost Creek, Racetrack Creek, Cottonwood Creek, Little Blackfoot River, Warm Springs Creek at Garrison, Gold Creek, Flint Creek, and Rock Creek (**Figure 6-2**). In 2017, additional juvenile otoliths were collected again in Gold creek (n= 5) and the lower Little Blackfoot (n = 10) river to get a better baseline for the chemical signatures of those streams. The otolith collection in 2017 in Gold Creek occurred at the same site that was sampled in 2016 because several otoliths from 2016 were damaged during preparation. The otoliths collected in the Little Blackfoot River in 2017 were from fish at previously unsampled sites in the downstream reaches. Twenty-four juvenile brown trout were also collected at four sites in the Clark Fork River to characterize chemical signature of the mainstem. These mainstem sites were located near Beavertail State Park (n = 5), Jens fishing access site (n=5), Kohrs river bend fishing access site (n=8), and near Racetrack pond (n=6). Five fish were also collected from Big Springs Trout Hatchery in Lewistown, MT. Brown trout from Big Springs Trout Hatchery have been used in the caged fish studies and have been stocked in the Warm Springs ponds. By adding these hatchery fish to the list of potential natal areas, we sought to account for possible escapement may have occurred from fish cages or the Warm Springs Ponds into the mainstem Clark Fork River.

Most of the juvenile fish collected were young of year. By using such young fish, we hoped to reduce the chance that these fish had undergone large movements, and thus been exposed to various geochemical environments, over their lifetime. We could therefore be confident that juvenile fish were spawned and reared near their location of capture and the chemical signature of their otoliths would reflect the signature of these natal areas. The selection of tributaries and sites from which juvenile otoliths were collected were based on locations with substantial spawning activity in a brown trout telemetry study [Mayfield, 2013). These sites often overlapped with standard annual electrofishing sections. The target sample size was 5 fish from each site.

After extraction, otoliths were wiped clean with paper towels and nylon brushes and stored in polypropylene centrifuge tubes. One otolith per fish was mounted to a microscope slide sulcus side up using Krazy Glue. Otoliths were sanded down to an even plane just above the primordium using a variety of sand paper and diamond lapping paper (1 µm and 0.5 µm). Sanded otoliths were rinsed with Type I (ultrapure) water and transferred and mounted to a final slide. Up to 12 sanded otoliths were mounted on each final slide to facilitate rapid processing with the LA-ICPMS.

Ratios of $^{87}Sr:^{86}Sr$, Sr:Ca, and Ba:Ca within otoliths were measured using a Neptune ICPMS equipped with a Nu Wave Research laser ablation device. The laser sampled otolith material along a transect from edge to edge passing through the primordium to provide chemical profiles over the lifetime of the fish (**Figure 6-3**). The laser was set to a scan speed of 5 µm per second, 75 µm spot size, a frequency of 20 Hz, and 100 percent power. A MACS3 standard was run periodically throughout each day so that instrument drift could be accounted for if necessary.

Measurements of $^{87}Sr:^{86}Sr$, Sr:Ca, and Ba:Ca were each averaged from all measurements taken across juvenile brown trout otoliths. Because most of the juvenile brown trout were not more than 1 year of age, we assumed that they had not moved significant distances from where they were spawned and reared. Therefore, we could consider the chemical measurements from the entire otolith to be representative of both their site of capture and their natal site. We used linear discriminant function analysis (DFA) to evaluate the extent to which these different natal sites had distinct chemical signatures. We used a cross-validated, leave one out (jackknife) procedure to classify juvenile fish to their natal area [Wells et al., 2003; Gibson-Reinemer et al., 2008]. $^{87}Sr:^{86}Sr$ and Ba:Ca ratios were log transformed to meet assumptions of normality and homogeneity of variance prior to modeling. In total, 117 juvenile otoliths from 22 different upper Clark Fork River basin sites and the Big Springs Fish Hatchery were used to develop the assignment model.

The DFA based on juvenile otolith signatures was then used to assign sub-adult and adult fish from the mainstem Clark Fork River to their natal areas. The signatures of previously unknown natal areas, taken from averages of chemical measurements from within the first annulus of adult and subadult brown trout (**Figure 6-3**), were entered into the model, which then assigns the otolith to natal areas defined by the juvenile fish DFA. This assignment model was used to classify the natal origin of 299 adult/subadult fish collected in the mainstem Clark Fork River.

6.2.2 Wild Fish Tissue Burdens

In 2016, a subset of fish from the mainstem Clark Fork River used for otolith collection also had tissues extracted for metal burden analyses. From each of the seven electrofishing sections, two fish per length category were selected for tissue metal burden analyses. Fish in the smallest category (not more than 175 mm) were to small to extract large enough tissue samples for analysis, so no fish in this length category were used in the analysis. For fish more than 175 mm, gills, liver, and stomachs were collected. Stomach contents were removed, and tissues were rinsed with deionized water and frozen until analysis. Samples were dissolved using microwave digestion and analyzed for copper, zinc, arsenic, lead, and cadmium concentrations using inductively coupled plasma optical emission spectrometry (ICP-OES). Ten brown trout were collected from Rock Creek in 2017 to provide reference tissue metals concentrations. Mean tissue metals concentrations for fish collected in 2016 were compared to concentrations from brown trout collected in 1992 in the vicinity of what is now referred to as the pH Shack Section [Farag et al., 1995].

6.2.3 Caged Fish Monitoring

The objective of caged fish monitoring in 2017 was to monitor for acute and residual impacts of construction activities. Cage locations were selected to bracket potential construction efforts that on Grant-Kohrs Ranch. Fish cages were placed below the outlet of Pond 2 to provide a site upstream of construction activities in Reach A and monitor habitability of water discharged by the Warm Springs Ponds. Cages were placed upstream of the I-90 bridge upstream of Deer Lodge to provide a site immediately upstream of construction activities. Cages were placed upstream of the Deer Lodge waste water treatment plant to provide a site immediately downstream of construction activities. The most downstream cages were placed at the Kohrs Fishing Access Site. Three cages were placed at each site. Twenty-five brown trout were placed in each cage on May 9th, 2017. Fish cages were checked for mortalities twice weekly. Any fish mortalities were collected and frozen. Three live fish were collected at each site the last week of every month of the study. The final cage checks were performed on September 12th, 2017 and all fish and cages were removed at this time.

After cages were deployed, it was decided that no construction activities would take place in 2017. The cages remained out for the normal duration of our intended study period and fish were collected as planned. In the past, fish were analyzed for copper and zinc. Since no work on the cleanup was completed in 2017, caged fish samples were not analyzed for metals.

6.2.4 Water Quality

Water quality parameters were recorded in the Clark Fork River at caged fish sites with continuously recording multiparameter water quality probes (Hydrolab ® MS5). Although no fish cages where installed at this location, an additional Hydrolab was placed near Racetrack bridge, primarily to monitor for low dissolved oxygen conditions recorded during past caged fish studies at this site [Cook et al., 2015]. Water quality parameters recorded include pH, temperature and dissolved oxygen (DO).

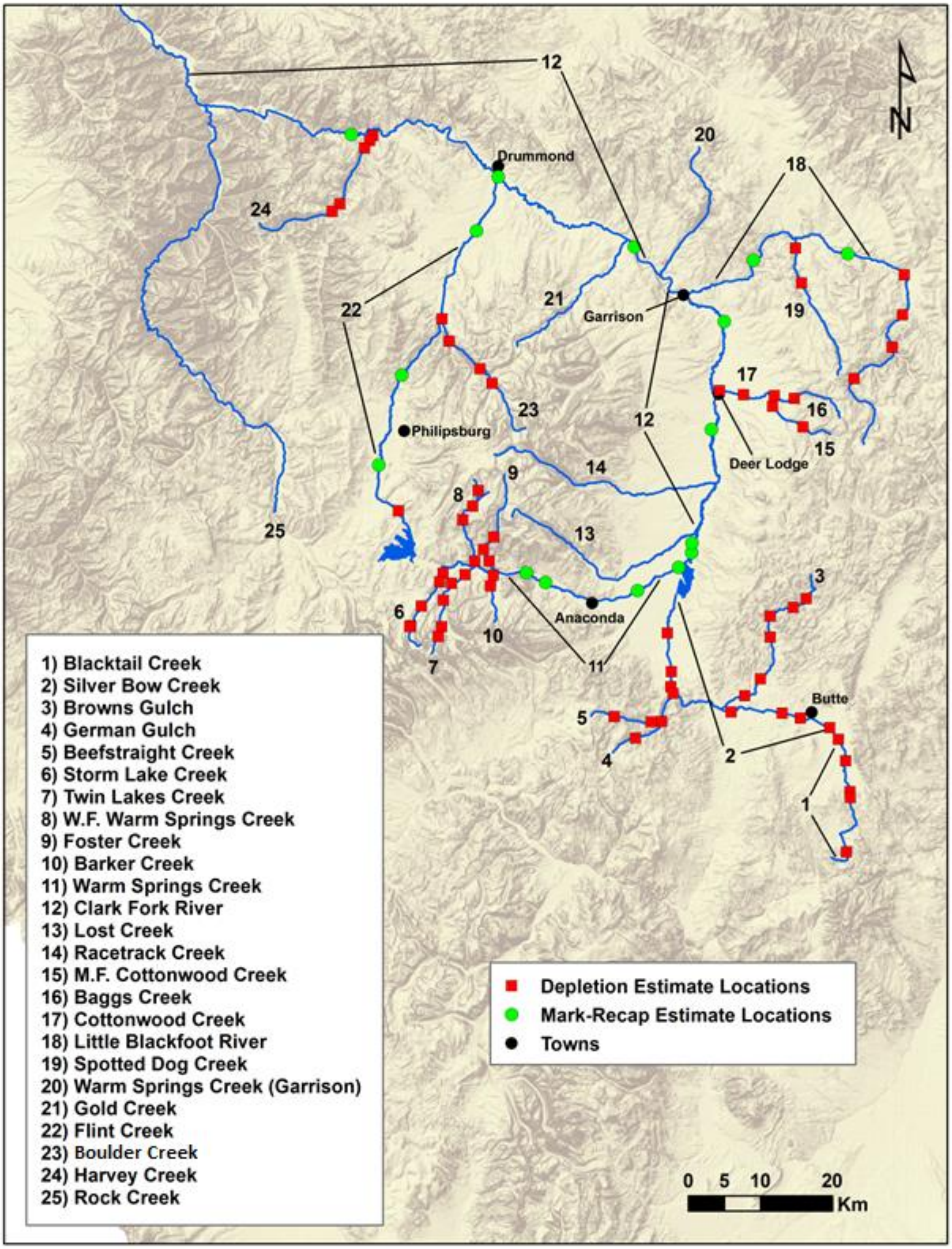

Figure 6-1. Map of electrofishing sections in the Upper Clark Fork River basin. Numbers refer to specific streams.

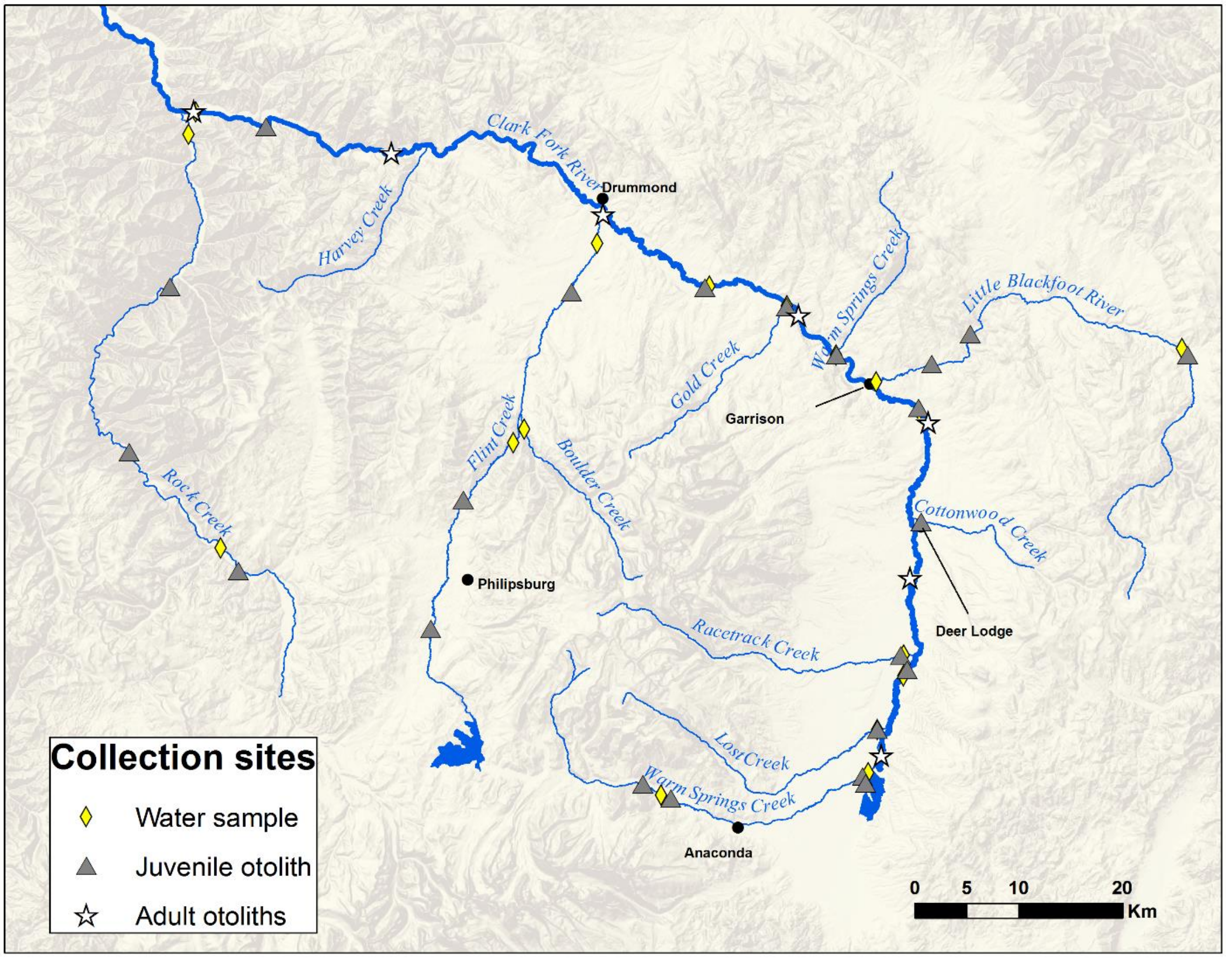

Figure 6-2. Map of water sampling locations and brown trout otolith collection sites for the otolith microchemistry study.

Table 6-1. Target sample allocation of fish collected for otoliths for the upper Clark Fork River brown trout microchemistry study.

Reach	Sampling section	Number of fish	Fish per length category
A	pH Shack	20	4
	Sager Lane	20	4
	Williams-Tavenner	20	4
B	Phosphate	25	5
	Morse Ranch	25	5
C	Bearmouth	25	5
	*Beavertail	25	5

*Beavertail was the only section not sampled as part of annual population surveys.

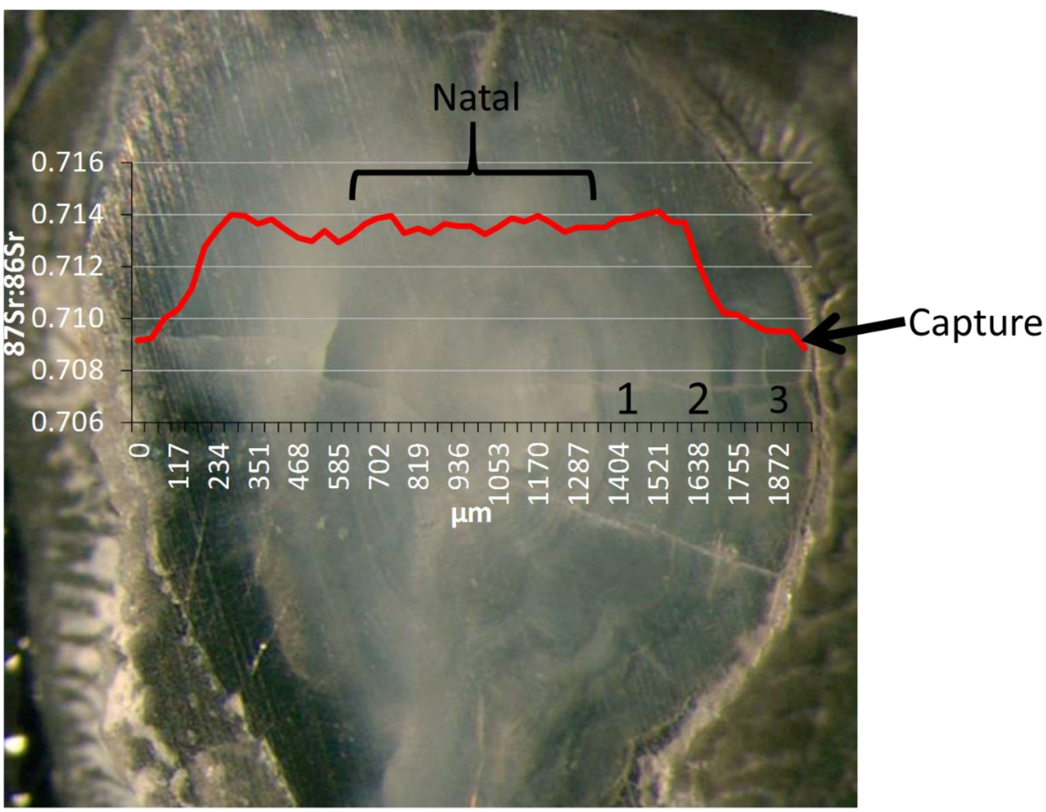

Figure 6-3. Example of a sanded brown trout otolith showing the approximate path of the laser transect on the x-axis for and corresponding strontium isotope ($^{87}Sr:^{86}Sr$) ratio on the y-axis.

6.3 RESULTS

6.3.1 Population Monitoring

6.3.1.1 Mainstem

Fish population estimates were conducted at seven sites on the Clark Fork River between Bearmouth and Warm Springs (**Table 6-2**). Brown trout were the most abundant trout species in all sections accounting for 62 to 99 percent of total trout present. Calculation of population estimates for rainbow trout and westslope cutthroat trout were only possible in the Bearmouth and Morse Ranch sections. Although these species were present in other sections, recapture numbers were too low to produce valid estimates. Eastern brook trout were captured in the Sager Lane section and one bull trout was captured in the Bearmouth section. Brown trout estimates ranged from 45 fish/km at Bearmouth to 331 fish/km at Phosphate. Brown trout abundance is as low as it has been since 2008 at the pH Shack section and since 2010 for the Below Sager Lane section (**Figure 6-4**). Brown trout population estimates at the other five sites were near or above average.

Table 6-2. Electrofishing data collected in 2017 from annual sampling sections on the upper Clark Fork River. Population estimates (95 percent confidence interval) are for trout greater than 175 mm (~ 7") in total length. Asterisks indicate species were combined for the population estimate.

Section	Species	Population Estimate (fish/km)	Fish Handled	Mean Length (mm)	Length Range (mm)	Species Composition (%)
Bearmouth	Brown Trout	45(32-67)	185	305	100-492	62
	Rainbow Trout	15(11-21)	93	312	195-460	31
	Westslope Cutthroat Trout	3(1-6)	19	324	204-420	6
	Bull Trout	NA	1	295	295	1
Morse Ranch	Brown Trout	90(76-108)	535	323	95-534	95
	Rainbow Trout	NA	4	302	245-362	4
	Westslope Cutthroat Trout	3(2-6)	24	288	214-452	1
Phosphate	Brown Trout	331(238-474)	328	323	94-474	98
	Westslope Cutthroat Trout	NA	6	334	269-382	2
Williams-Tavenner	Brown Trout	203(142-299)	267	336	111-500	98
	Westslope Cutthroat Trout	NA	5	354	297-404	2
	Rainbow Trout x Westslope Cutthroat Trout phenotypic hybrid	NA	1	284	284	<1
Below Sager Lane	Brown Trout	92(65-133)	227	319	101-500	97
	Brook Trout	NA	4	210	194-223	2
	Westslope Cutthroat Trout	NA	2	305	304-306	1
pH Shack to Perkins Lane	Brown Trout	140(93-220)	154	298	105-479	99
	Rainbow Trout	NA	2	312	129-495	1
pH Shack	Brown Trout	140(98-210)	177	317	104-493	97
	Rainbow Trout	NA	5	410	170-593	2
	Westslope Cutthroat Trout	NA	1	237	237	1

NA Not applicable due to insufficient data.

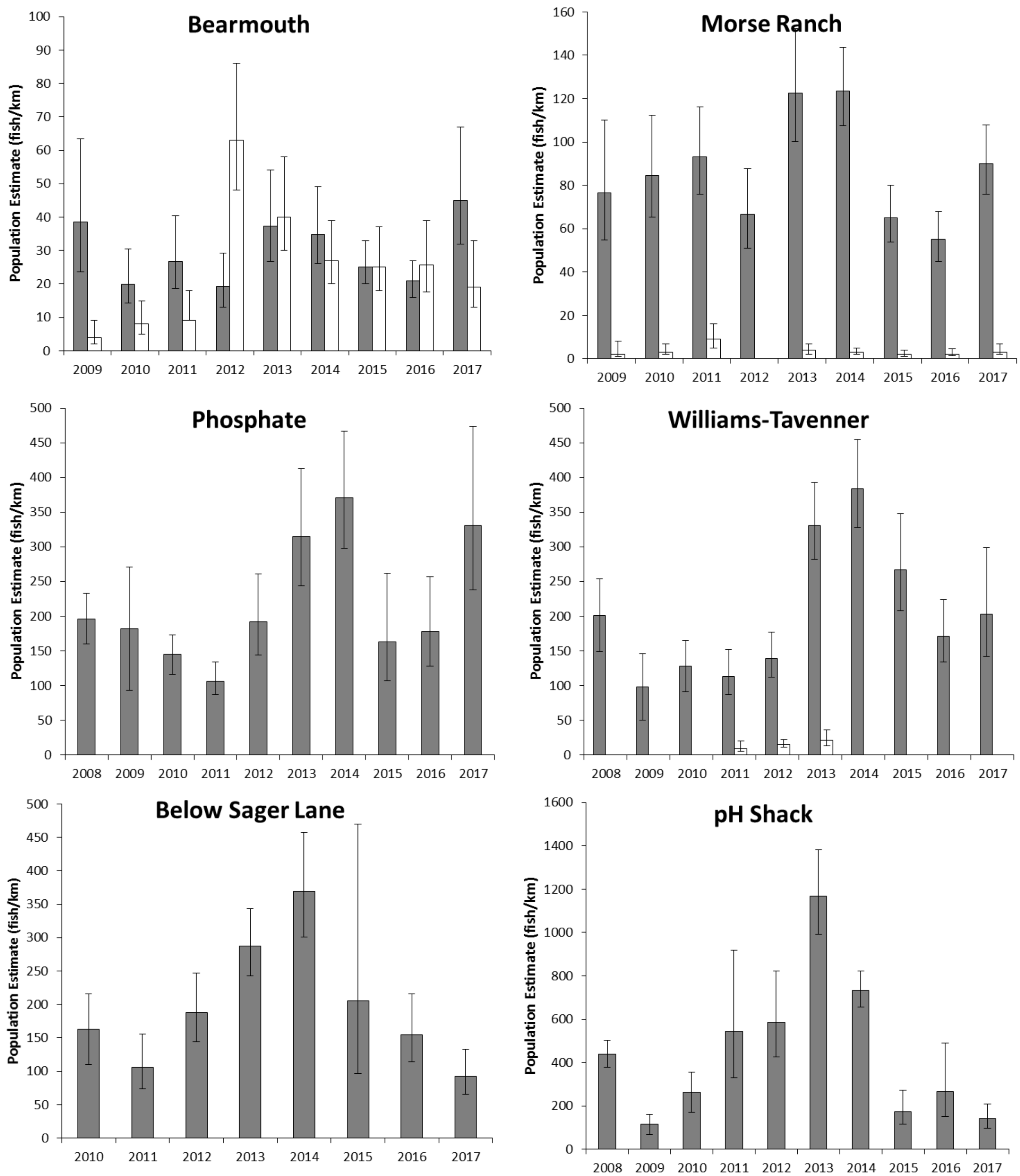

Figure 6-4. Clark Fork River brown trout (grey bars) and Oncorhynchus sp. (white bars) population estimates from 2008-2017 by sample section. Sample reaches are displayed from downstream to upstream, left to right then top to bottom. Please note that axis values are not the same for every sample reach.

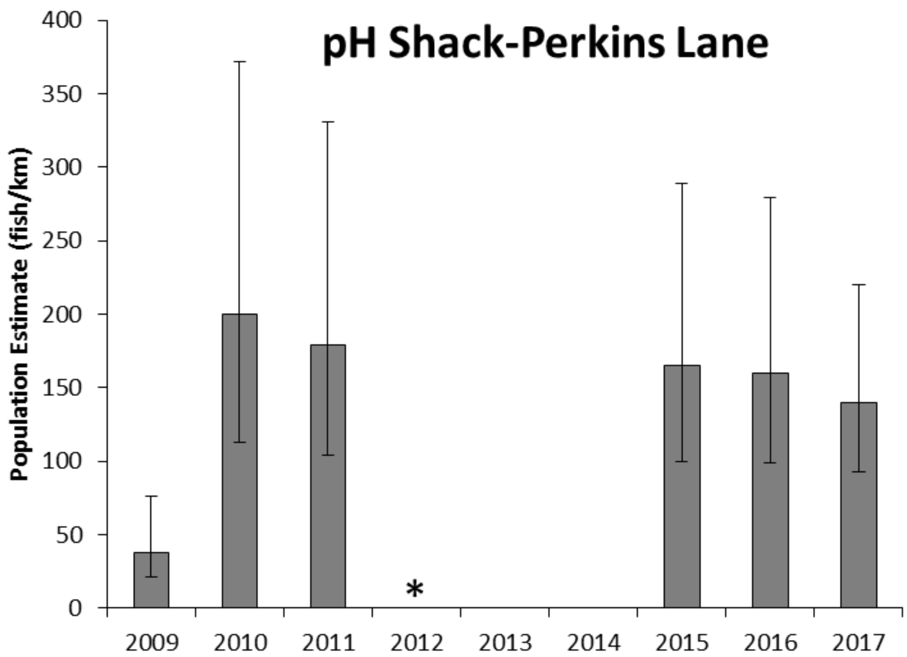

Figure 6-5. Clark Fork River brown trout population estimates from the pH Shack to Perkins Lane sampling section. Asterisk indicates that only one fish was recaptured in 2012 so reliable estimate could not be calculated. Tributaries

6.3.1.2 Tributaries

Between July 5 and October 12, 2017, a total of 76 sections comprising 19.8 km of stream were sampled in tributaries of the Upper Clark Fork River and Silver Bow Creek. Sixty-eight depletion estimates and eight mark-recapture population estimates were conducted on these waters. Electrofishing data are presented for each watershed below. Data from Silver Bow Creek and its tributaries are presented in their own section of this report.

6.3.1.2.1 Warm Springs Creek and Tributaries

Nineteen depletion estimates and four mark/recapture estimates were conducted in the Warm Springs Creek watershed (Table 6-3; Table 6-4; Table 6-5; Table 6-6; Table 6-7). Five electrofishing sections were sampled on Storm Lake Creek with westslope cutthroat trout being the most abundant species in all but the lowest section comprising of 40-77 percent of fish (**Table 6-3**). Brook trout accounted for 50 percent of the trout sampled in the lowest section while westslope cutthroat trout made up 38 percent. Brook trout, bull trout, brook trout-bull-trout hybrids, rainbow trout and rainbow trout-westslope cutthroat trout hybrids were also present in other sections. There were no non-trout species captured in any section of Storm Lake Creek.

Five sections were sampled on Twin Lakes Creek with westslope cutthroat trout being the most common trout species in all but one section comprising 48-72 percent of all trout (**Table 6-4**). Brook trout were most the most abundant (69 percent) trout species in the section downstream of the lower lake. Bull trout were present in all sections except RM 4.6 and brook trout were present in all but the uppermost and lowest sections. Three brown trout were captured in the lowest sampling section representing the first time this species has been sampled in Twin Lakes Creek. Sculpin were found in all sections. Rocky Mountain sculpins and slimy sculpins are in the drainage with some overlap throughout the length of the stream. With the difficulty in field identification, it is possible that some sculpins were misidentified. More rigorous sculpin identification may need to be done in the future.

Three sections were sampled on Foster Creek (**Table 6-5**). Westslope cutthroat trout were most abundant in all sections and accounted for 51-84 percent of fish present. Brook trout were present in all sections. Bull trout were only present in the lowest section. Rainbow trout were present in the lower section and rainbow trout-westslope cutthroat trout hybrids were present in the upper and lower section.

Two sections were sampled on Barker Creek (**Table 6-6**). Bull trout accounted for 70-71 percent of fish. Westslope cutthroat trout were present in both sections. No sculpins were captured.

Warms springs Creek (including the West Fork) had eight estimate sections with brown trout comprising 86-99 percent of fish in the two sections below Myers dam. Westslope cutthroat trout were most abundant in four of the five sections above Meyers dam and accounted for 59-100 percent of fish in those sections (**Table 6-7**). Brook trout were present in four sections and were most abundant in the section at RM 27.4 making up 76 percent of trout. Bull trout were present in four sections. Brook trout-bull trout hybrids were found in two sections. Rocky Mountain sculpins were present in the lowest two sections. Slimy sculpins were present in the middle three sections and no sculpin were observed in the upper three sections. Brown trout were observed for the first time in the section above Veronica Trail Road at RM 26.0.

Table 6-3. Electrofishing data collected on Storm Lake Creek in 2017. Population estimates (95 percent confidence interval) are for trout greater than 75 mm (~3 in) in total length.

Section	Species	Population Estimate (fish/100 m)	Fish Handled	Mean Length (mm)	Length Range (mm)	Species Composition (%)
Lower (RM 0.6)	Westslope Cutthroat Trout	15(15-16)	16	156	55-232	38
	Brook Trout	22(21-26)	21	118	75-225	50
	Bull Trout	NA	1	193	193	2
	Rainbow Trout	NA	4	172	143-185	10
Above First Crossing (RM 1.4)	Westslope Cutthroat Trout	26(26-28)	33	143	32-236	55
	Brook Trout	24(24-25)	24	128	77-223	44
	Bull Trout	NA	2	78	70-86	3
	Rainbow Trout x Westslope Cutthroat Trout phenotypic hybrid	NA	1	154	154	2
Lower Meadow (RM 4.2)	Westslope Cutthroat Trout	40(40-42)	46	145	58-222	65
	Rainbow Trout	NA	1	313	313	1
	Bull Trout	8(8-11)	13	100	23-243	18
	Brook Trout x Bull Trout phenotypic hybrid	NA	4	190	77-234	6
	Brook Trout	7(7-8)	7	117	88-185	10
Below upper Storm Lake road crossing (RM 6.3)	Westslope Cutthroat Trout	20(20-22)	42	94	55-185	40
	Brook Trout	NA	3	189	180-200	3
	Bull Trout	27(26-30)	27	91	45-131	25
	Brook Trout x Bull Trout phenotypic hybrid	NA	1	172	172	1
	Rainbow Trout x Westslope Cutthroat Trout phenotypic hybrid	19(19-20)	29	96	55-164	27
	Rainbow Trout	NA	4	138	59-294	4
Above upper Storm Lake road crossing (RM 6.3)	Westslope Cutthroat Trout	49(45-57)	68	108	54-267	77
	Brook Trout	4(4-6)	5	175	45-241	6
	Bull Trout	14(14-16)	15	101	26-162	17

NA Not applicable because data insufficient.

RM River mile; measured upstream from river mouth.

Table 6-4. Electrofishing data collected on Twin Lakes Creek in 2017. Population estimates (95 percent confidence interval) are for trout greater than 75 mm (~3") in total length.

Section	Species	Population Estimate (fish/100 m)	Fish Handled	Mean Length (mm)	Length Range (mm)	Species Composition (%)
Lower (RM 1.3)	Westslope Cutthroat Trout	14(14-16)	13	159	104-230	72
	Bull Trout	NA	1	86	86	6
	Brown Trout	NA	3	117	112-120	16
	Rainbow Trout x Westslope Cutthroat Trout phenotypic hybrid	NA	1	115	115	6
Meadow (RM 2.8)	Westslope Cutthroat Trout	13(13-14)	15	121	62-217	48
	Brook Trout	16(15-20)	15	133	80-194	48
	Bull Trout	NA	1	151	151	4
Upstream of old bridge (RM 4.6)	Westslope Cutthroat Trout	21(21-23)	22	122	69-180	69
	Brook Trout	NA	2	86	79-93	6
	Slimy Sculpin	NA	8	73	47-95	25
Downstream of lower lake (RM 7.2)	Westslope Cutthroat Trout	NA	3	130	122-136	23
	Brook Trout	NA	9	105	66-160	69
	Bull Trout	NA	1	183	183	8
Upstream of upper lake (RM 8.5)	Westslope Cutthroat Trout	39(32-46)	26	120	47-307	57
	Bull Trout	14(13-15)	20	88	32-157	43

NA Not applicable because data insufficient.

RM River mile; measured upstream from river mouth.

Table 6-5. **Electrofishing data collected on Foster Creek in 2017. Population estimates (95 percent confidence interval) are for trout greater than 75 mm (~3 in) in total length.**

Section	Species	Population Estimate (fish/100m)	Fish Handled	Mean Length (mm)	Length Range (mm)	Species Composition (%)
Lower (RM 1.0)	Westslope Cutthroat Trout	45(42-51)	43	150	34-305	51
	Bull Trout	5(5-6)	5	173	162-180	6
	Brook Trout	NA	3	110	62-138	4
	Rainbow Trout	NA	5	122	103-143	6
	Rainbow Trout x Westslope Cutthroat Trout phenotypic hybrid	28(28-29)	28	119	86-177	33
Middle (RM 2.3)	Westslope Cutthroat Trout	48(47-51)	50	106	70-223	78
	Brook Trout	6(6-6)	14	89	45-160	22
Upper (RM 3.8)	Westslope Cutthroat Trout	92(89-97)	103	123	50-212	84
	Brook Trout	18(18-20)	18	108	80-164	14
	Rainbow Trout x Westslope Cutthroat Trout phenotypic hybrid	NA	1	134	134	1

NA Not applicable because data insufficient.

RM River mile; measured upstream from river mouth.

Table 6-6. **Electrofishing data collected on Barker Creek in 2017. Population estimates (95 percent confidence interval) are for trout greater than 75 mm (~3 in) in total length.**

Section	Species	Population Estimate (fish/100 m)	Fish Handled	Mean Length (mm)	Length Range (mm)	Species Composition (%)
Lower (RM 0.5)	Bull Trout	40(38-45)	39	146	43-184	71
	Westslope Cutthroat Trout	15(15-16)	16	177	64-251	29
RM 1.5	Bull Trout	30(29-34)	31	151	45-578	70
	Westslope Cutthroat Trout	13(13-14)	13	160	107-255	30

NA Not applicable because data insufficient.

RM River mile; measured upstream from river mouth.

Table 6-7. Electrofishing data collected on Warm Springs Creek in 2017. Population estimates (95 percent confidence interval) are for trout greater than 75 mm (~3 in) in total length.

Section	Species	Population Estimate (fish/100 m)	Fish Handled	Mean Length (mm)	Length Range (mm)	Species Composition (%)
Wildlife Management Area (RM 3.3)	Brown Trout	135(120-153)	749	174	64-487	99
	Rainbow Trout	NA	1	282	282	<1
	Westslope Cutthroat Trout	NA	2	277	114-330	<1
Below Meyers Dam	Brown Trout	99(86-115)	563	193	68-408	86
	Rainbow Trout x Westslope Cutthroat Trout phenotypic hybrid	2(1-8)	11	196	123-354	2
	Rainbow Trout	4(3-10)	25	185	110-385	4
	Brook Trout	NA	6	126	59-162	1
	Bull Trout	2(1-5)	16	236	174-494	2
	Westslope Cutthroat Trout	7(3-15)	31	190	102-344	5
Garrity WMA (Above Meyers Dam)	Westslope Cutthroat Trout	49(40-62)	225	165	45-343	59
	Rainbow Trout x Westslope Cutthroat Trout phenotypic hybrid	20(16-27)	46	145	89-309	12
	Brown Trout	5(4-9)	49	196	75-340	13
	Bull Trout	10(5-25)	30	220	108-430	8
	Rainbow Trout	4(3-8)	28	175	102-425	7
	Brook Trout x Bull Trout phenotypic hybrid	1(1-3)	1	224	224	<1
	Brook Trout	NA	2	146	130-162	<1
Above Veronica Trail (RM 26.0)	Westslope Cutthroat Trout	27(23-31)	42	148	76-256	70
	Brook Trout	NA	9	165	95-349	15
	Bull Trout	NA	2	204	116-292	3
	Brown Trout	NA	1	180	180	2
	Slimy Sculpin	NA	6	71	40-95	10
Below Upper Bridge (RM 27.4)	Brook Trout	26(25-30)	25	164	82-287	76
	Westslope Cutthroat Trout	7(7-8)	7	193	138-322	21
	Brook Trout x Bull Trout phenotypic hybrid	NA	1	302	302	3
Below Confluence of Upper Forks	Westslope Cutthroat Trout	44(40-53)	40	148	92-215	98
	Bull Trout	NA	1	175	175	2
	Westslope Cutthroat Trout	24(24-25)	29	105	48-182	100

NA Not applicable because data insufficient.

RM River mile; measured upstream from river mouth.

6.3.1.2.2 Cottonwood Creek and Tributaries

Four depletion estimates were conducted on five sections in Cottonwood Creek and one of its tributaries, Baggs Creek (Table 6-8; Table 6-9). In Cottonwood Creek, brown trout were the only trout species captured in the lowest section. Several young of year brown trout were captured in this section. The section at river mile 3.0 was generally depauperate of fish, probably due to dewatering. No depletion estimate was conducted at this section. Westslope cutthroat trout and brook trout numbers were similar in the upper section with westslope cutthroat trout making up 52 percent of fish and brook trout accounting for 48 percent. There were many young of year brook trout in this section that were not included in the total numbers of fish present. Rocky Mountain sculpins were captured at the lower site and slimy sculpins were captured at the upper site. In the Middle Fork of Cottonwood Creek, westslope cutthroat trout made up 80 percent of fish and brook trout 20 percent. No other fish were observed in this section.

One section was surveyed on Baggs Creek with similar numbers of westslope cutthroat trout (80) and brook trout (78) being handled. No other fish species were observed in this section. The lower section on Baggs Creek was not surveyed in 2017 due to lack of time and trouble getting a hold of the landowner for access.

Table 6-8. Electrofishing data collected on Cottonwood Creek in 2017. Population estimates (95 percent CI) are for trout greater than 75 mm (~3 in) in total length.

Section	Species	Population Estimate (fish/100 m)	Fish Handled	Mean Length (mm)	Length Range (mm)	Species Composition (%)
School (RM 0.8)	Brown Trout	101(94-110)	127	150	47-335	95
	Rocky Mountain Sculpin	NA	7	117	102-138	5
Middle (RM 3.0)	Brown Trout	NA	10	135	52-184	72
	Brook Trout	NA	3	78	50-128	21
	Sculpin	NA	1	113	113	7
Upper (RM 6.9)	Westslope Cutthroat Trout	71(67-78)	71	105	65-201	52
	Brook Trout	67(65-71)	65	119	85-212	48
	Rocky Mountain Sculpin	NA	93	unk	46-96	
Middle Fork	Westslope Cutthroat Trout	115(110-122)	136	111	52-231	80
	Brook Trout	34(33-37)	33	109	80-213	20

NA Not applicable because data insufficient.

unk Unknown.

RM River mile; measured upstream from river mouth.

Table 6-9. Electrofishing data collected on Baggs Creek in 2017. Population estimates (95 percent CI) are for trout greater than 75 mm (~3 in) in total length.

Section	Species	Population Estimate (fish/100 m)	Fish Handled	Mean Length (mm)	Length Range (mm)	Species Composition (%)
RM 2.4	Westslope Cutthroat Trout	70(66-76)	80	115	66-246	51
	Brook Trout	64(60-70)	78	114	46-190	49

RM River mile; measured upstream from river mouth.

6.3.1.2.3 Little Blackfoot River and Tributaries

Mark recapture estimates were conducted on two sections and depletion estimates were conducted on six sections in the Little Blackfoot River and one of its tributaries (Table 6-10; Table 6-11). In the lower four sections of the Little Blackfoot River, brown trout were the most abundant trout species, accounting for 42-99 percent of all fish captured. Many mountain whitefish were observed in the lower two sections but were not netted due to time constraints. Rocky Mountain sculpins were also present in the lower section. Westslope cutthroat trout were the most abundant trout species in the upper two sections making up 41-52 percent of fish present. Brook trout were present in all but the lowest section. Mountain whitefish were present in all sections but there were fewer present in the upper sections.

Two depletion estimates were done on Spotted Dog Creek. Brown trout were the most abundant species in both sections making up 42-90 percent of fish. Sculpins were present in both sections and were not used to calculate the species composition. Longnose suckers and largescale suckers were present in the lower section. Brook trout and longnose suckers were present in both sections.

Table 6-10. Electrofishing data collected on the Little Blackfoot River in 2017. Population estimates (95 percent CI) are for trout greater than 75 mm (~3 in) in total length.

Section	Species	Population Estimate (fish/100 m)	Fish Handled	Mean Length (mm)	Length Range (mm)	Species Composition (%)
Rest Area - FWP FAS	Brown Trout	77(70-85)	660	248	101-490	99
	Westslope Cutthroat Trout	NA	4	306	255-332	1
Above N. Trout Creek	Brown Trout	32(28-37)	316	212	101-405	94
	Brook Trout	NA	4	199	122-259	1
	Westslope Cutthroat Trout	2(1-5)	15	284	230-344	5
Above Hwy 12 Bridge near Elliston (RM 26.7)	Mountain Whitefish	11(10-12)	32	328	272-380	15
	Brown Trout	35(33-36)	115	164	55-335	54
	Westslope Cutthroat Trout	10(10-11)	32	234	102-336	15
	Brook Trout	5(5-6)	22	118	64-229	11
	Longnose Sucker	NA	11	133	84-256	5
Above Sunshine Camp	Westslope Cutthroat Trout	9(7-11)	17	138	73-280	30
	Brown Trout	13(9-17)	24	173	38-400	42
	Mountain Whitefish	NA	3	297	270-330	5
	Brook Trout	3(2-4)	8	109	55-140	14
	Longnose Sucker	NA	5	120	93-186	9
Below Ontario Creek (RM 34.9)	Westslope Cutthroat Trout	43(33-52)	53	120	64-278	52
	Brown Trout	42(13-70)	34	128	78-230	33
	Mountain Whitefish	NA	6	207	110-287	6
	Brook Trout	NA	9	109	90-139	9
Above Kading Campground (RM 40.1)	Westslope Cutthroat Trout	25(22-28)	49	135	67-218	41
	Brook Trout	23(19-27)	42	122	67-222	35
	Brown Trout	10(6-15)	19	145	72-293	16
	Mountain Whitefish	5(4-6)	10	155	85-251	8

NA Not applicable because data insufficient.

RM River mile; measured upstream from river mouth.

Table 6-11. Electrofishing data collected on Spotted Dog Creek in 2017. Population estimates (95 percent CI) are for trout greater than 75 mm (~3 in) in total length.

Section	Species	Population Estimate (fish/100 m)	Fish Handled	Mean Length (mm)	Length Range (mm)	Species Composition (%)
RM 1.1	Brown Trout	35(30-45)	45	235	79-380	90
	Westslope Cutthroat Trout	NA	1	286	286	2
	Longnose Sucker	NA	2	170	166-173	4
	Brook Trout	NA	1	215	215	2
	Largescale Sucker	NA	1	162	162	2
RM 4.6	Westslope Cutthroat Trout	5(4-6)	16	137	52-233	32
	Brown Trout	7(6-8)	21	216	162-307	42
	Brook Trout	4(3-5)	13	108	79-187	26

NA Not applicable because data insufficient.

RM River mile; measured upstream from river mouth.

6.3.1.2.4 Flint Creek and Tributaries

Three mark-recapture and one depletion estimate were conducted on Flint Creek and four depletion estimates were conducted on Boulder Creek (Table 6-12; Table 6-13). In the four Flint Creek sections, brown trout comprised 98-99 percent of the fish captured. Many mountain whitefish were observed in the three lowest sections but were not netted. Westslope cutthroat trout were captured in the lower three sections, brook trout in the Chor section and rainbow trout in the upper three sections. Rocky Mountain sculpins were observed in only the lowest section. One bull trout was captured in each of the lowest two sections.

Brown trout were the most abundant fish in the lower two sections of Boulder Creek accounting for 49 percent and 58 percent of fish captured. Bull trout were present in all four sections and relatively abundant in the upper two sections making up 56 percent and 53 percent of fish captured. Westslope cutthroat trout were present in all four sections with their numbers being similar at each. Phenotypic brook trout-bull trout hybrids were observed in the section at RM 6.5. One rainbow trout-westslope cutthroat trout hybrid was observed at the RM 2.0 site and one brook trout was captured at the RM 6.5 site.

Table 6-12. Electrofishing data collected on Flint Creek in 2017. Population estimates (95 percent CI) are for trout greater than 175 mm (~7 in) in total length for the Hall, Johnson Tuning Fork and Chor.

Section	Species	Population Estimate (fish/km)	Fish Handled	Mean Length (mm)	Length Range (mm)	Species Composition (%)
Hall	Brown Trout	493(424-582)	442	267	170-517	99
	Westslope Cutthroat Trout	NA	5	294	225-363	1
	Bull Trout	NA	1	284	284	<1
Johnson Tuning Fork	Brown Trout	340(286-414)	266	266	166-462	99
	Rainbow Trout	8(5-23)	282	282	205-400	3
	Westslope Cutthroat Trout	3(2-10)	310	310	299-318	1
	Bull Trout	NA	240	240	240	<1
Chor	Brown Trout	324(287-371)	269	269	269	97
	Brook Trout	NA	229	229	229	2
	Rainbow Trout	NA	345	345	345	<1
	Westslope Cutthroat Trout	NA	329	329	329	<1
Dam (Above Campground)	Brown Trout	39(34-49)	258	258	258	98
	Rainbow Trout	NA	340	340	340	2

NA Not applicable because data insufficient.

Table 6-13. Electrofishing data collected on Boulder Creek in 2017. Population estimates (95 percent CI) are for trout greater than 75 mm (~3 in) in total length.

Section	Species	Population Estimate (fish/100 m)	Fish Handled	Mean Length (mm)	Length Range (mm)	Species Composition (%)
USGS Gage (RM 0.4)	Brown Trout	18(18-20)	18	177	81-382	49
	Westslope Cutthroat Trout	17(17-19)	17	185	85-326	46
	Bull Trout	NA	2	229	187-270	5
RM 2.0	Brown Trout	37(32-47)	32	163	99-369	58
	Westslope Cutthroat Trout	19(19-21)	21	159	73-330	38
	Bull Trout	NA	1	56	56	2
	Rainbow Trout x Westslope Cutthroat Trout phenotypic hybrid	NA	1	331	331	2
Princeton Bridge (RM 6.5)	Bull Trout	43(36-54)	44	154	60-339	56
	Westslope Cutthroat Trout	22(22-23)	26	147	78-297	33
	Brook Trout x Bull Trout phenotypic hybrid	NA	5	183	121-225	6
	Brown Trout	NA	3	240	191-298	4
	Brook Trout	NA	1	135	135	1
Copper Lakes Trailhead	Bull Trout	17(17-18)	17	178	91-453	53
	Westslope Cutthroat Trout	13(13-14)	15	170	69-261	47

NA Not applicable because data insufficient.

RM River mile; measured upstream from river mouth.

6.3.1.2.5 Harvey Creek

Only four of six estimate sections were completed on Harvey Creek in 2017 (**Table 6-14**). Access to the upper two sections was restricted due to wildfires. Westslope cutthroat trout made up 99-100 percent of trout in the lower four sections. Bull trout were present in the middle two sections. Sculpin were present in the lower four sections but were not enumerated. Young of the year westslope cutthroat trout were abundant in most sections.

Table 6-14. Electrofishing data collected on Harvey Creek in 2017. Population estimates (95 percent CI) are for trout greater than 75 mm (~3 in) in total length.

Section	Species	Population Estimate (fish/100 m)	Fish Handled	Mean Length (mm)	Length Range (mm)	Species Composition (%)
RM 0.6	Westslope Cutthroat Trout	28(27-32)	27	159	101-270	
RM 1.2	Westslope Cutthroat Trout	41(39-45)	47	149	92-308	
RM 1.6	Westslope Cutthroat Trout	74(70-81)	70	156	91-299	
	Bull Trout	NA	1	244	244	
RM 2.3	Westslope Cutthroat Trout	59(55-66)	71	134	47-305	
	Bull Trout	NA	2	206	142-270	

NA Not applicable because data insufficient.

RM River mile; measured upstream from river mouth.

6.3.2 Microchemistry

Values of $^{87}Sr{:}^{86}Sr$, Sr:Ca and Ba:Ca measured in juvenile fish otoliths were highly correlated to measurements of these chemical markers in water samples taken near to their location of capture (**Figure 6-6**). The relationship of $^{87}Sr{:}^{86}Sr$ in water and otoliths was nearly 1:1. Values of Sr:Ca and Ba:Ca were lower in otoliths compared to corresponding water samples. Sr:Ca values in otoliths increased linearly with increasing water values, whereas Ba:Ca values displayed more of a logarithmic relationship.

Based on otolith chemistry, the DFA correctly classified individual juvenile fish to their location on capture for 79 percent of the samples (**Figure 6-7**). Most of the errors occurred when fish were misclassified to other sites within the same stream where they were captured. For example, only one out of five (20 percent) of the fish captured at the middle site on Rock Creek was correctly classified to its capture site. The other four fish from this site were classified to the other sites with Rock Creek. Individual juvenile fish from the mainstem were correctly classified to their site of capture for 60-100 percent of the samples, but when errors occurred, the fish were misclassified to other mainstem sites. All of the individual fish from Cottonwood, Gold, Garrison Warm Springs, Lost, and Flint creeks were correctly classified to their capture sites. All of the hatchery fish were also correctly classified. Individuals from the three sites within Warm Springs Creek were correctly classified to their capture sites in 80-100 percent of the cases. Little Blackfoot River were correctly classified in 60-100 percent of the cases. Classification of Mill Willow Bypass fish had the lowest accuracy with only 17 percent of the fish correctly assigned to this area. Examining the variables produced by the DFA, the multivariate chemical signature of most tributaries was distinct from one another (**Figure 6-8**). Some sites with the same tributary were also distinct, particularly sites in Flint Creek and Warm Springs Creek. There was considerable overlap in the signatures of sites within Rock Creek. Mainstem sites also tended to overlap with each other and also overlapped with sites in Mill-Willow Bypass and Racetrack Creek.

Subadult and adult brown trout captured in the mainstem were assigned to natal areas in every tributary examined as well as natal areas within the mainstem itself (**Table 6-15**). None of the fish from unknown natal origin assigned to the hatchery. Overall, the most fish were assigned to natal areas in the mainstem, particularly in Reach A. Gold Creek contributed a greater percentage (17.7 percent) of the fish than any other natal area. The Mill-Willow Bypass and Rock Creek contributed 12.0 percent and 11.7 percent of the fish sampled. The Little Blackfoot River, Garrison Warm Springs, and Cottonwood Creek contributed the fewest fish of the tributaries at 1.3 percent, 0.7 percent, and 0.3 percent, respectively. When we examine recruitment sources for reaches A, B, and C, the overall pattern is that fish tended to be assigned to recruitment sources near their location of capture (**Table 6-16**). The largest recruitment sources for fish captured in Reach A were the mainstem of Reach A (32.8 percent), Mill-Willow Bypass (24.1 percent), and Warm Springs Creek (17.2 percent). For Reach B fish, Gold Creek was the largest recruitment source with 46.2 percent of the fish assigned to this tributary. Rock Creek was the largest source of Reach C fish (37.8 percent) followed by Flint Creek (17.8 percent). Most of the fish assigned to Rock Creek assigned to the most upstream site near Gilles Bridge, but the ability of the DFA to differentiate the sites within Rock Creek was limited.

6.3.3 Wild Fish Tissue Burdens

We are currently awaiting lab results of the brown trout tissue burdens from Rock Creek. These data will serve as a control to compare tissue burdens from fish from the mainstem Clark Fork River. This analysis will be included in the comprehensive Upper Clark Fork River Basin Fisheries Monitoring Report.

6.3.4 Caged Fish Monitoring

The temperature logger at the I-90 bridge site failed, so no temperature data were not available from this site. Overall, mortalities tended to occur on the descending limb of the hydrograph as water temperatures increased over 19°C (**Figure 6-9**; **Figure 6-10**; **Figure 6-11**; **Figure 6-12**). This is a pattern consistent with past caged fish studies in the UCFR. Water temperatures exceeded the upper critical temperature of 19°C for 74 days at Pond 2, 76 days at the Deer Lodge Waste Water Treatment Plant, and 80 days at Kohrs Bend. Water temperatures exceeded the upper incipient lethal temperature of 24.7°C for 1 day at Pond 2, 0 days at the Deer Lodge Waste Water Treatment, and 2 days at Kohrs Bend.

There were 49 mortalities at the Pond 2 site, 43 mortalities at the I-90 Bridge, 9 at the Deer Lodge Waste Water Treatment Plant, and 28 mortalities at Kohrs Bend. Metals tissue burdens were not analyzed for cage fish in 2017 because no remediation activities took place.

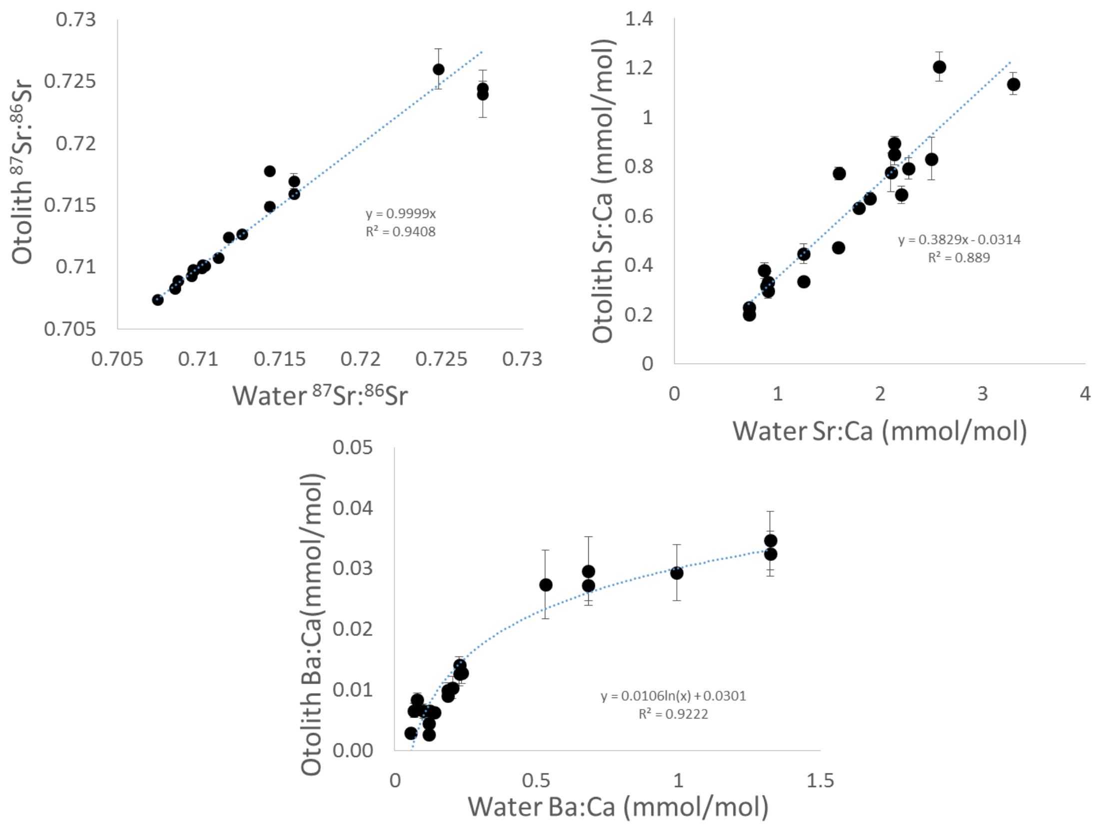

Figure 6-6. Average juvenile otolith ^{87}Sr:^{86}Sr, Sr:Ca and Ba:Ca values (error bars are SD) from different sites throughout the Upper Clark Fork River basin compared to values from water samples collected at nearby locations. No water sample was collected in Cottonwood Creek, so data from in Cottonwood Creek are not included in this figure.

		Assigned																						
		CF-A1	CF-A2	CF-B	CF-C	MWB	WS-U	WS-M	WS-L	LC	RTC	CW	LBF-U	LBF-M	LBF-L	GWS	GC	FC-U	FC-M	FC-L	RC-U	RC-M	RC-L	HAT	%correct
Captured	CF-A1	4																							100
	CF-A2	1	6	1																					75
	CF-B			4	1																				80
	CF-C		1	1	3																				60
	MWB	2	2			1					1														17
	WS-U						4	1																	80
	WS-M							5																	100
	WS-L								5																100
	LC									5															100
	RTC			1		1					3														60
	CW											5													100
	LBF-U												6												100
	LBF-M													3	2										60
	LBF-L													1	4										80
	GWS															4									100
	GC																7								100
	FC-U																	5							100
	FC-M																		5						100
	FC-L																			4					100
	RC-U																				2		2		50
	RC-M																				1	1	3		20
	RC-L																					2	3		60
	HAT																							4	100
	Total	7	9	7	4	2	4	6	5	5	4	5	6	4	6	4	7	5	5	4	3	3	8	4	**79**

Figure 6-7. Accuracy of discriminant function analysis to classify juvenile brown trout to the site from which they were captured based on otolith chemical profiles. Values in each cell are numbers of fish, except the rightmost column which is of the percent of fish captured at a site that were correctly classified to that site. Grey cells on the diagonal are fish correctly classified to their capture site.[65]

[65] Site codes are: CF-A1, Clark Fork River Reach A #1; CF-A2, Clark Fork River Reach A #2; CF-B. Clark Fork River Reach B; CF-C, Clark Fork River Reach C; MWB, Mill-Willow Bypass; WS-U, Warm Springs Creek – Upper; WS-M, Warm Springs Creek – Middle; WS-L, Warm Springs Lower; LC, Lost Creek; RTC, Racetrack Creek; CW, Cottonwood Creek; LBF-U, Little Blackfoot River – Upper; LBF-M, Little Blackfoot River – Middle; LBF-L, Little Blackfoot River – Lower; GWS, Garrison Warm Springs; GC, Gold Creek; FC-U, Flint Creek – Upper; FC-M, Flint Creek – Middle; FC-L, Flint Creek – Lower; RC-U, Rock Creek - Upper; RC-M, Rock Creek - Middle; RC-L, Rock Creek – Lower; HAT, Big Springs Hatchery.

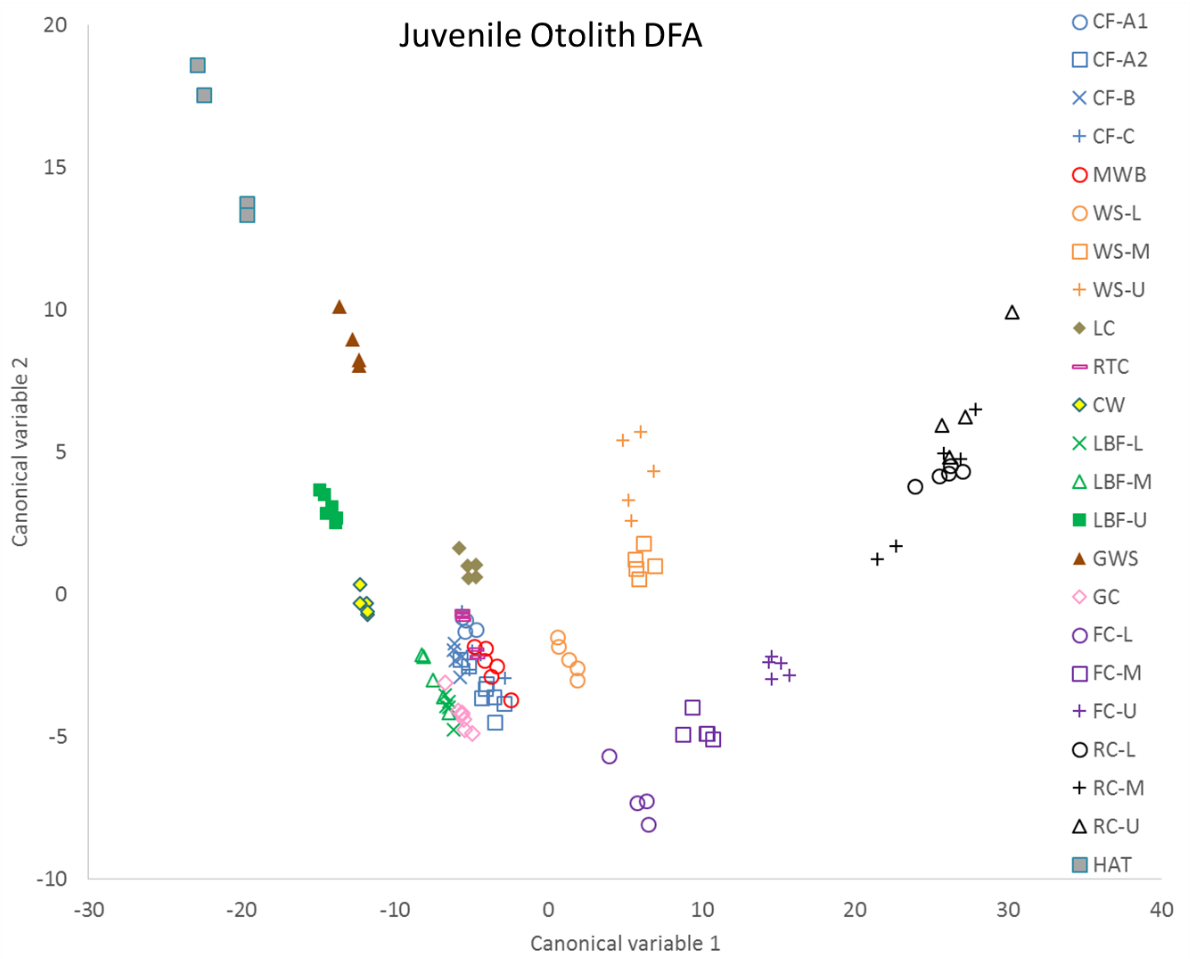

Figure 6-8. Results of discriminant function analysis used to characterize multivariate chemical signatures of juvenile brown trout otoliths. Data points are individual fish. Data points of the same color are from the same stream. Data points of the same color and shape are from the same site.[66]

[66] Site codes are: CF-A1, Clark Fork River Reach A #1; CF-A2, Clark Fork River Reach A #2; CF-B. Clark Fork River Reach B; CF-C, Clark Fork River Reach C; MWB, Mill-Willow Bypass; WS-U, Warm Springs Creek – Upper; WS-M, Warm Springs Creek – Middle; WS-L, Warm Springs Lower; LC, Lost Creek; RTC, Racetrack Creek; CW, Cottonwood Creek; LBF-U, Little Blackfoot River – Upper; LBF-M, Little Blackfoot River – Middle; LBF-L, Little Blackfoot River – Lower; GWS, Garrison Warm Springs; GC, Gold Creek; FC-U, Flint Creek – Upper; FC-M, Flint Creek – Middle; FC-L, Flint Creek – Lower; RC-U, Rock Creek - Upper; RC-M, Rock Creek - Middle; RC-L, Rock Creek – Lower; HAT, Big Springs Hatchery.

Table 6-15. Natal area assignment results of brown trout captured in seven sections of the mainstem Upper Clark River. Numbers of fish from each mainstem capture sections assigned to different natal areas are presented as well as total numbers of fish assigned to each natal area and natal stream. The percentage of the total number of fish assigned to natal streams is also presented.[67]

Natal Area		Capture Section							Natal Area Total	Natal Stream Total	Natal Stream %
		Reach A			Reach B		Reach C				
Stream	Site	PH	SL	WT	PE	MR	BM	BT			
Clark Fork River	CF-A1	9	13	4	1	8	8	3	46	87	29.10%
	CF-A2	3	1	8	2	3	0	0	17		
	CF-B	0	0	4	3	4	2	0	13		
	CF-C	1	0	7	2	0	1	0	11		
Mill-Willow Bypass	MWB	10	14	4	4	1	2	1	36	36	12.00%
Warm Springs Ck.	WS-L	11	6	3	2	0	0	1	23	23	7.70%
	WS-M	0	0	0	0	0	0	0	0		
	WS-U	0	0	0	0	0	0	0	0		
Lost Ck.	LC	1	0	0	3	2	1	5	12	12	4.00%
Racetrack Ck.	RTC	1	4	6	3	3	3	3	23	23	7.70%
Cottonwood Ck.	CW	0	1	0	0	0	0	0	1	1	0.30%
Little Blackfoot R.	LBF-L	0	0	0	0	0	0	1	1	4	1.30%
	LBF-M	0	0	3	0	0	0	0	3		
	LBF-U	0	0	0	0	0	0	0	0		
Garrison-Warm Sp.	GWS	0	0	0	2	0	0	0	2	2	0.70%
Gold Ck.	GC	0	0	1	26	17	7	2	53	53	17.70%
Flint Ck.	FC-L	0	1	0	0	5	8	1	15	23	7.70%
	FC-M	0	0	0	0	1	2	1	4		
	FC-U	0	0	0	0	0	1	3	4		
Rock Ck.	RC-L	0	0	0	0	0	1	5	6	35	11.70%
	RC-M	0	0	0	0	0	4	4	8		
	RC-U	0	0	0	0	1	7	13	21		
Hatchery	HAT	0	0	0	0	0	0	0	0	0	0%
Capture Section Total		36	40	40	48	45	47	43			

[67] Capture section codes are: PH, pH Shack; SL, Sager Lane; WT, Williams Tavenner; PE, Phosphate; MR, Morse Ranch; BM, Bearmouth; BT, Beavertail. Natal site codes are: CF-A1, Clark Fork River Reach A #1; CF-A2, Clark Fork River Reach A #2; CF-B. Clark Fork River Reach B; CF-C, Clark Fork River Reach C; MWB, Mill-Willow Bypass; WS-U, Warm Springs Creek – Upper; WS-M, Warm Springs Creek – Middle; WS-L, Warm Springs Lower; LC, Lost Creek; RTC, Racetrack Creek; CW, Cottonwood Creek; LBF-U, Little Blackfoot River – Upper; LBF-M, Little Blackfoot River – Middle; LBF-L, Little Blackfoot River – Lower; GWS, Garrison Warm Springs; GC, Gold Creek; FC-U, Flint Creek – Upper; FC-M, Flint Creek – Middle; FC-L, Flint Creek – Lower; RC-U, Rock Creek - Upper; RC-M, Rock Creek - Middle; RC-L, Rock Creek – Lower; HAT, Big Springs Hatchery.

Table 6-16. Results of brown trout natal area assignment summarized by reach in which the fish was captured.[68]

Natal area		Capture reach		
Stream	**Site**	**A**	**B**	**C**
Clark Fork R.	CF-A1	22.40%	9.70%	12.20%
	CF-A2	10.30%	5.40%	0.00%
	CF-B	3.40%	7.50%	2.20%
	CF-C	6.90%	2.20%	1.10%
Mill-Willow Bypass	MWB	24.10%	5.40%	3.30%
Warm Springs Cr.	WS-L	17.20%	2.20%	1.10%
	WS-M	0.00%	0.00%	0.00%
	WS-U	0.00%	0.00%	0.00%
Lost Cr.	LC	0.90%	5.40%	6.70%
Racetrack Cr.	RTC	9.50%	6.50%	6.70%
Cottonwood Cr.	CW	0.90%	0.00%	0.00%
Little Blackfoot R.	LBF-L	0.00%	0.00%	1.10%
	LBF-M	2.60%	0.00%	0.00%
	LBF-U	0.00%	0.00%	0.00%
Garrison-Warm Sp.	GWS	0.00%	2.20%	0.00%
Gold Cr.	GC	0.90%	46.20%	10.00%
Flint Cr.	FC-L	0.90%	5.40%	10.00%
	FC-M	0.00%	1.10%	3.30%
	FC-U	0.00%	0.00%	4.40%
Rock Cr.	RC-L	0.00%	0.00%	6.70%
	RC-M	0.00%	0.00%	8.90%
	RC-U	0.00%	1.10%	22.20%
Hatchery	HAT	0.00%	0.00%	0.00%

[68] Capture section codes are: PH, pH Shack; SL, Sager Lane; WT, Williams Tavenner; PE, Phosphate; MR, Morse Ranch; BM, Bearmouth; BT, Beavertail. Natal site codes are: CF-A1, Clark Fork River Reach A #1; CF-A2, Clark Fork River Reach A #2; CF-B. Clark Fork River Reach B; CF-C, Clark Fork River Reach C; MWB, Mill-Willow Bypass; WS-U, Warm Springs Creek – Upper; WS-M, Warm Springs Creek – Middle; WS-L, Warm Springs Lower; LC, Lost Creek; RTC, Racetrack Creek; CW, Cottonwood Creek; LBF-U, Little Blackfoot River – Upper; LBF-M, Little Blackfoot River – Middle; LBF-L, Little Blackfoot River – Lower; GWS, Garrison Warm Springs; GC, Gold Creek; FC-U, Flint Creek – Upper; FC-M, Flint Creek – Middle; FC-L, Flint Creek – Lower; RC-U, Rock Creek - Upper; RC-M, Rock Creek - Middle; RC-L, Rock Creek – Lower; HAT, Big Springs Hatchery.

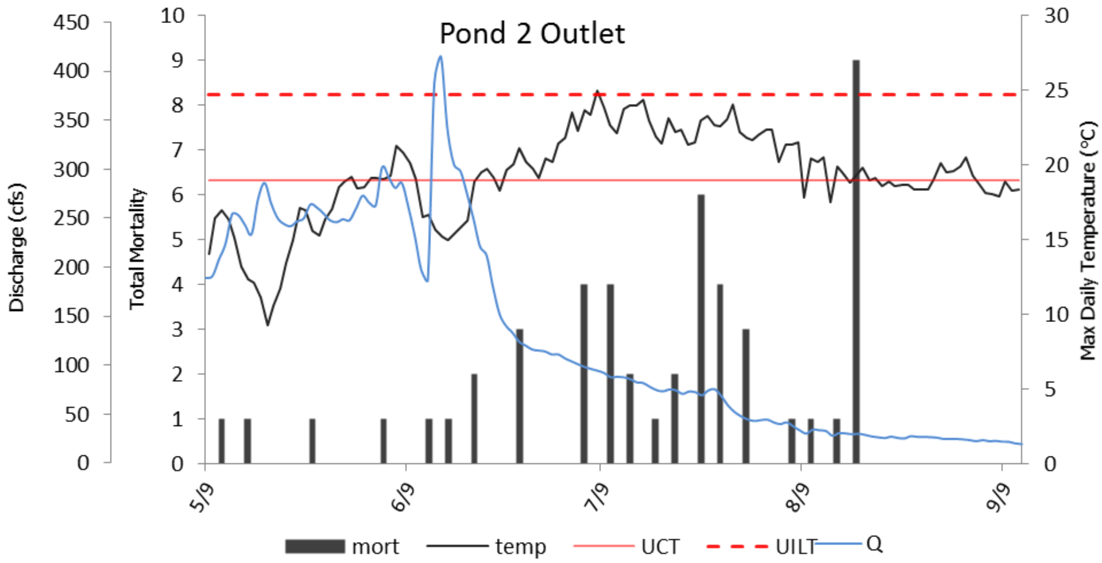

Figure 6-9. Total fish mortalities, maximum daily water temperature, and mean daily discharge for Silver Bow Creek at the outlet of Pond 2. The solid red line indicates the upper critical temperature threshold and the dashed red line represents the upper incipient lethal temperature for brown trout.

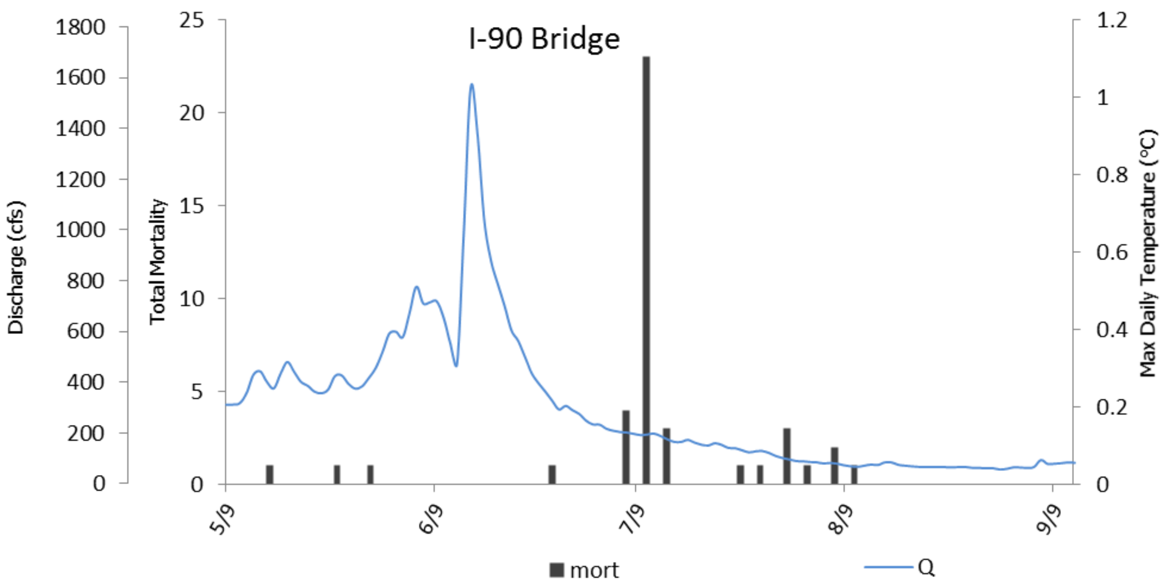

Figure 6-10. Total fish mortalities, maximum daily water temperature, and mean daily discharge for the I-90 Bridge site. The temperature recorder at this site failed so no temperature data are available.

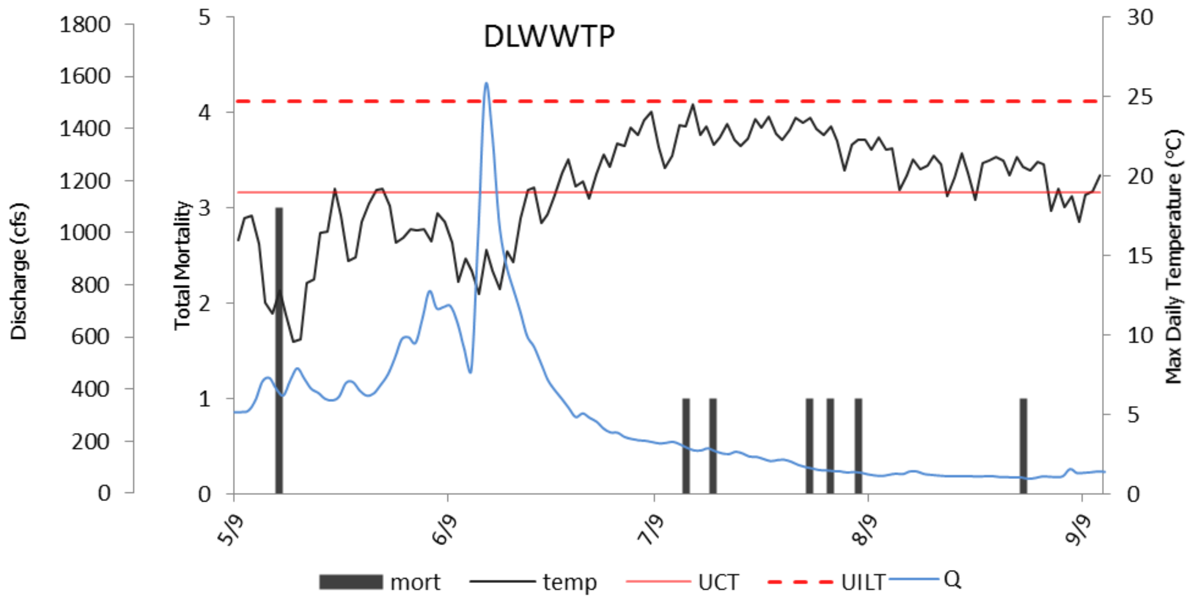

Figure 6-11. Total fish mortalities, maximum daily water temperature, and mean daily discharge for the Deer Lodge Waste Water Treatment Plant site. The solid red line indicates the upper critical temperature threshold and the dashed red line represents the upper incipient lethal temperature for brown trout.

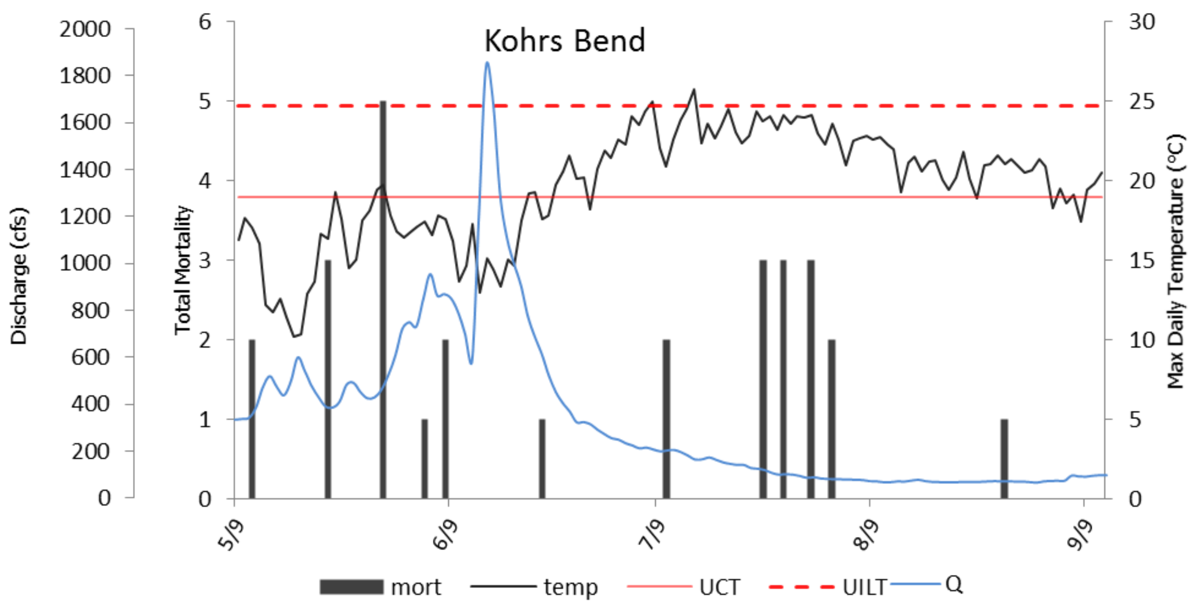

Figure 6-12. Total fish mortalities, maximum daily water temperature, and mean daily discharge for the Kohrs Bend site. The solid red line indicates the upper critical temperature threshold and the dashed red line represents the upper incipient lethal temperature for brown trout.

6.3.5 Water Quality

Measurements of pH during the month of August and in early September at the Pond 2 site routinely exceeded 10 (**Figure 6-13**). The Hydrolab at the Pond 2 site was temporarily moved to the Mill-Willow Bypass on 8/1 to accommodate maintenance on the dam and outlet. At the other sites studied in 2017, pH ranged from 7.4 to 9.0. Daily variations at the Pond 2 site were lower than at the other sites. As would be expected, pH at all sites increased during the day and decreased at night due to changes in photosynthetic activity. The Hydrolab sensor failed at the Deer lodge Treatment plant on 8/13/18, so data after this date were not available.

Dissolved oxygen (DO) values at the six sites ranged from 4.2 to 14.7 mg/L (**Figure 6-14**). Lowest DO occurred at night and highest during the day. Daily minimum DO at the Racetrack site approached the minimum aquatic life standard of 4 mg/L, but did not dip below this value. Daily variations in DO were largest at the Racetrack site, suggesting significant biologic activity in the Clark Fork River upstream of this site.

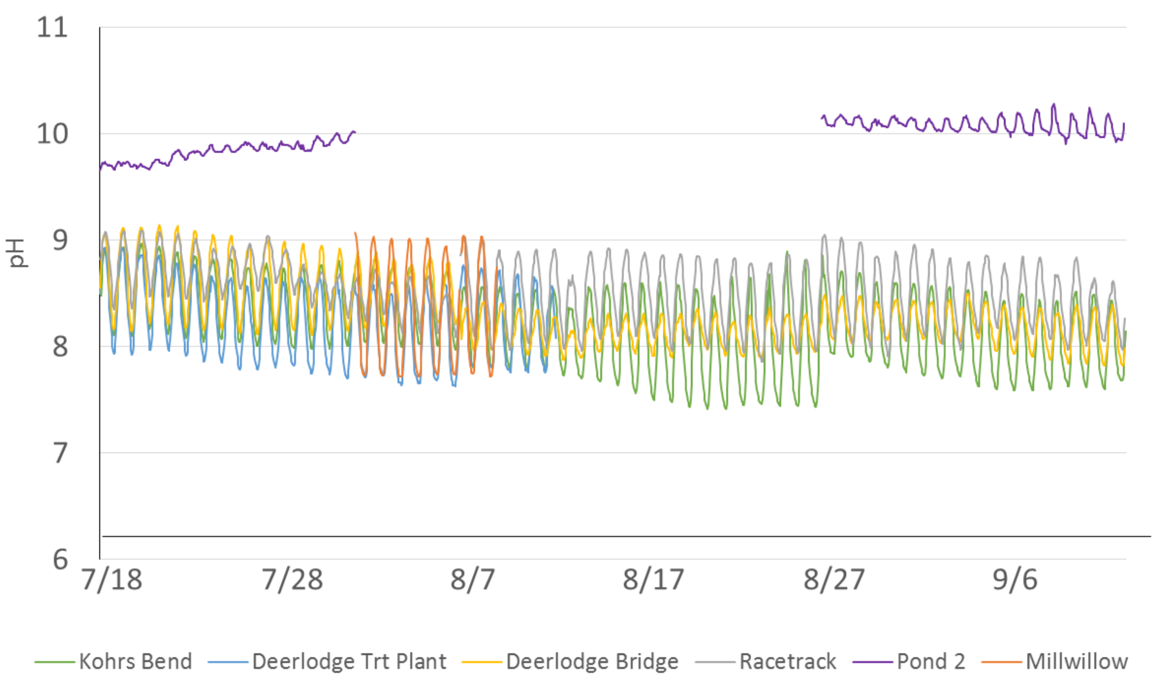

Figure 6-13. Hydrolab measurements of pH at six sites in the Upper Clark Fork River during 2017. The Hydrolab at the Pond 2 site was temporarily moved to the Mill-Willow Bypass on 8/1 to accommodate maintenance activities on the Pond 2 outlet structure.

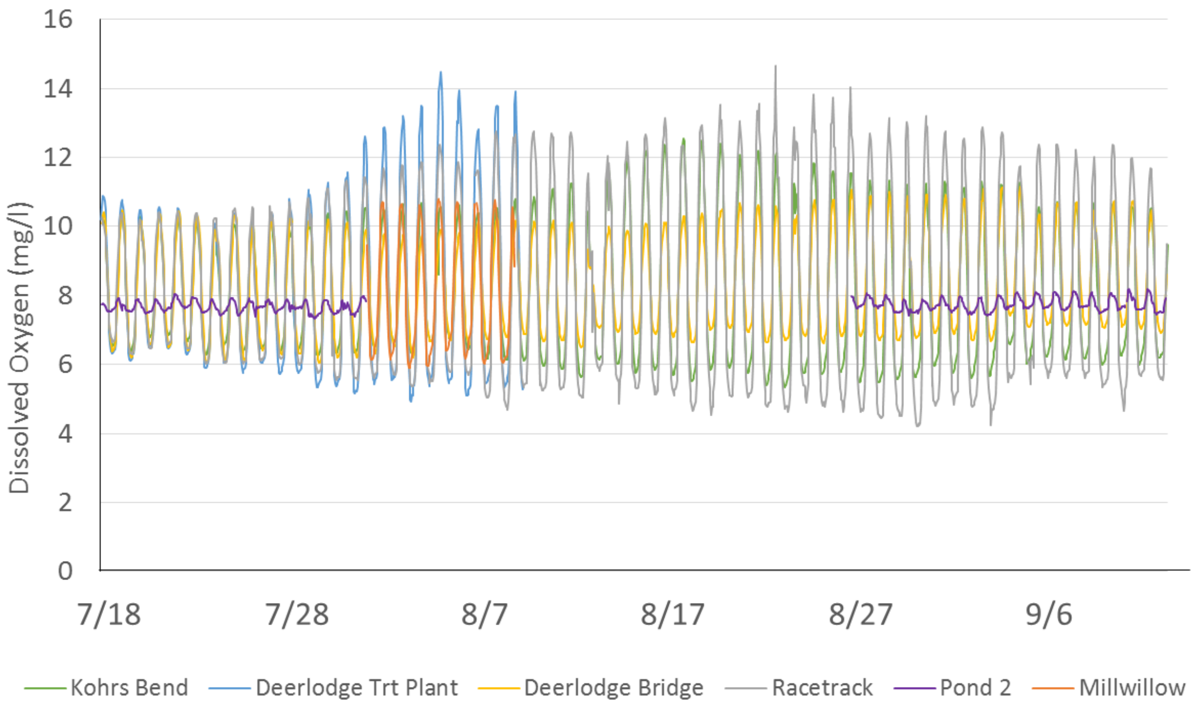

Figure 6-14. Minimum daily dissolved oxygen (DO) concentrations at 2016 caged fish sites. The red dashed horizontal line denotes the freshwater ALS minimum DO. Gaps in the graph indicate missing data due to instrument failures and calibration.

6.4 DISCUSSION

Brown trout numbers at the two most upstream population estimate sections have been relatively low in recent years. Brown trout population estimates in 2017 at the pH Shack section of the Upper Clark Fork River were the lowest recorded since 2009. At the Below Sager Lange section, brown trout numbers were the lowest ever observed since annual population estimates began in 2010. Continued drought-like conditions during the summer months appear to be negatively impacting the brown trout population in the upper reaches of the Clark Fork River. 2017 was the last of a three-year effort to produce annual population estimates at more than 75 sections in 18 tributaries. Fish population data from these three years will be compiled with any past data and presented in a comprehensive report.

Brown trout numbers in 2017 continued to be low in the two most upstream sections of the Clark Fork River that have been sampled every year. This is in contrast to brown trout numbers at the more downstream stations which were at, or even slightly above, average. Brown trout numbers in the upstream reaches of the Clark Fork River are related to flow conditions in the years leading up to the population estimate. For instance, increases in numbers in 2013 and 2014 were due to due strong year classes from 2010 and 2011, which were good water years (**Figure**

6-15). The higher flows during these years may have provided additional spawning and/or rearing habitats that are not are not available at lower flows. The low flow period that follows runoff in the UCFR has been shown to be a period of high mortality for juvenile brown trout [Richards et al., 2013; Cook et al., 2014]. The upper Clark Fork River routinely exceeds 19°C during the summer, often for weeks at a time. The increase in fish mortality is presumably due to thermal stress, which may be exasperated by toxicity of heavy metals such as Cu.

Population estimates have been conducted at the 77 tributary sampling sections in this study in 2015, 2016, and 2017. However, two of the sections could not be sampled in 2017 due to wildfires and one other could not be sampled because the landowner could not be reached to gain access. Overall, these tributary sampling events will provide valuable baseline data that can be used to evaluate future restoration actions in the upper Clark Fork River basin. Tributary fish population data from all three years will be summarized in a comprehensive report in 2018.

Otolith microchemistry proved to be a useful tool for quantifying recruitment sources in the upper Clark Fork River basin. The assignment model based on measurements of otolith $^{87}Sr:^{86}Sr$, Sr:Ca and Ba:Ca ratios had good power to assign fish to natal tributaries, and in some cases, to specific sites. Adult and subadult brown trout in the mainstem Clark Fork River tended to come from natal areas near their location of capture. This general lack of movement is consistent with telemetry data [Mayfield, 2013] that showed that Clark Fork River do not move around very much, except during spawning season. Mainstem natal areas, including the Mill-Willow Bypass, are major sources of brown trout recruitment to the upstream reaches of the Clark Fork River. Fish from as far downstream as Beavertail were assigned to natal areas in Reach A and the Mill-Willow Bypass, indicating the importance of the recruitment of upstream natal areas to downstream reached of the Clark Fork River. Reach A has the highest concentrations of metal contamination, is the most impacted by low water during irrigation, and brown trout in this reach also have the highest mortality [Mayfield, 2013; Coot et al., 2015]. Despite these limiting factors, enough young brown trout this area of the Clark Fork River survive to make a significant contribution to the populations.

The main sources of brown trout recruitment to Reach A are natal areas within the mainstem. This is in contrast to the main sources for reaches B and C which are natal areas within tributaries. Gold Creek was the single largest recruitments source, contributing 18 percent of all the brown trout sampled in this study and 46 percent of the brown trout from Reach B. Gold was also a major source of fish for Reach C, as well. Rock Creek was the largest source of fish to Reach C, contributing 22 percent of the fish in that reach. Flint Creek was also a major contributor of fish to Reach C, again highlighting the importance of local tributary sources of trout recruitment. Similarly, the largest tributary source of recruitment to Reach A was Warm Springs. Therefore, tributaries such as Gold Creek, Rock Creek, Flint Creek, and Warm Springs should be high priority areas for restoration activities that can maintain or enhance the capacity of these streams to provide trout to the mainstem.

Only 4 of the 299 (1.3 percent) mainstem brown trout analyzed in the microchemistry study assigned to natal areas within the Little Blackfoot River. This number is surprisingly low considering that the Little Blackfoot River was the most common tributary spawning destination for brown trout that were radio tagged in the mainstem Clark Fork River [Mayfield, 2013]. Although it is common for adults to move from the Clark Fork River to the Little Blackfoot River to spawn, it is uncommon for their progeny, or the progeny of resident Little Blackfoot River spawners, to survive moving into the Clark Fork River. It is possible that there are habitat limitations that prevent fish from out-migrating from the Little Blackfoot River such as irrigation diversions.

No remediation related construction occurred in 2017, but caged fish monitoring was still conducted. Fish cages have been placed at the outlet of Pond 2 annually from 2011-2017. Fish at the Pond 2 site experienced the highest mortality of all fish cages sites in 2017. From year to year, fish in the Pond 2 fish cages consistently have high mortality rates compared to other locations in the upper Clark Fork River basin [Cook et al., 2014]. Brown trout (both caged and free-ranging) immediately downstream of the Warm Springs Ponds tend to have relatively low metals concentrations compared to locations near Deer Lodge and upstream of the Little Blackfoot River. Therefore, toxicity of metals does not appear to be a primary driver of high fish mortality immediately below the Warm Springs Ponds. Other likely culprits include high summer water temperatures combined with high pH. A laboratory study found high mortality (more than 81 percent) of rainbow trout exposed to water with pH above 8.4 and temperatures above 20°C [Wagner et al., 1997], conditions that are exceeded every year downstream of the Warm Springs Ponds.

Dissolved oxygen monitoring indicated that DO concentrations did not go below the minimum aquatic life standard of 4 mg/L at any of the six locations. In 2016, DO at the Racetrack site dipped below the ALS during 14 nights in 2016, reaching concentrations as low as 2.9 mg/L. In 2017, DO at the Racetrack site approached 4 mg/L on several occasions during August and September. Large daily variation in DO at the Racetrack site (**Figure 6-14**) are driven by biological activity as photosynthesis leads to an increase in DO during the day and respiration depletes DO at night. Dissolved oxygen should be continued to be monitored at Racetrack as the biological community continues to adjust to completed remediation and restoration activities in this area of the Clark Fork River.

Patterns from caged fish monitoring did not indicate any acute negative effects from cleanup activities. Mortality patterns in 2016 caged fish monitoring were consistent with caged fish studies in previous years. Mortalities tend to peak as flows subsided and temperatures increased. Tissue metals burdens were generally similar between sites. One exception was brown trout zinc burdens at the Pond 2 site. Although water concentrations of zinc in the Pond 2 outflow are relatively low, brown trout at this site had higher zinc concentrations than 11 other caged fish sites in the upper Clark Fork River basin in 2014 [Cook et al., 2014]. It appears that the mechanism of zinc accumulation at this site is not simply a function of exposure to dissolved zinc in the water column. Macroinvertebrates are abundant at the Pond 2 outflow, and fish at this site grow quickly. Caged fish are fed pellet food twice a week, but macroinvertebrates may provide a diet subsidy. This subsidy may provide a pathway for zinc accumulation in fish residing below the Warm Springs Ponds.

Water quality data indicated that the number of days where pH exceeded 10 at the Pond 2 outflow was lower that is has been for three years. However, the pH of this water is still high (more than 9) during the most of summer months, creating unfavorable and potentially toxic conditions for trout. Extended exposure to pH more than 9 may be harmful to trout [Colt et al., 1979] and results in higher ammonia toxicity [DEQ, 2017]. Dissolved oxygen concentrations reached levels as low as 2.9 mg/L at the Racetrack caged fish site. The lowest DO levels occurred during warm summer nights when biological oxygen demand was high, and supply from photosynthesis was low. Although no fish mortalities appeared to be related to hypoxia at the Racetrack site, any DO concentrations less than the ALS of 4.0 mg/L are cause for concern. Water quality monitoring at Racetrack in 2015 revealed that DO concentrations dipped below 4.0 mg/L for one night in August [Cook et al., 2015]. In 2016 monitoring, DO reached levels below 4.0 mg/L on 14 nights at Racetrack. Given the questionable water quality observed at Pond 2 and Racetrack in recent years, it is advisable to continue water quality monitoring at these sites.

Additional fisheries monitoring data will be collected in the upper Clark Fork River basin in 2017. This data collection includes repeating population estimates at mainstem and tributary sampling sections, collected and analyzing additional otoliths for the microchemistry study, and caged fish monitoring of cleanup activities. These data will be integrated into a comprehensive report that will describe the current status of trout populations in the upper Clark Fork River basin, trout recruitment dynamics and movement, and limiting environmental factors. As restoration and remediation progress in the upper Clark Fork River basin, these data will serve as a baseline and guide for future evaluations of how fish respond to improved aquatic habitats.

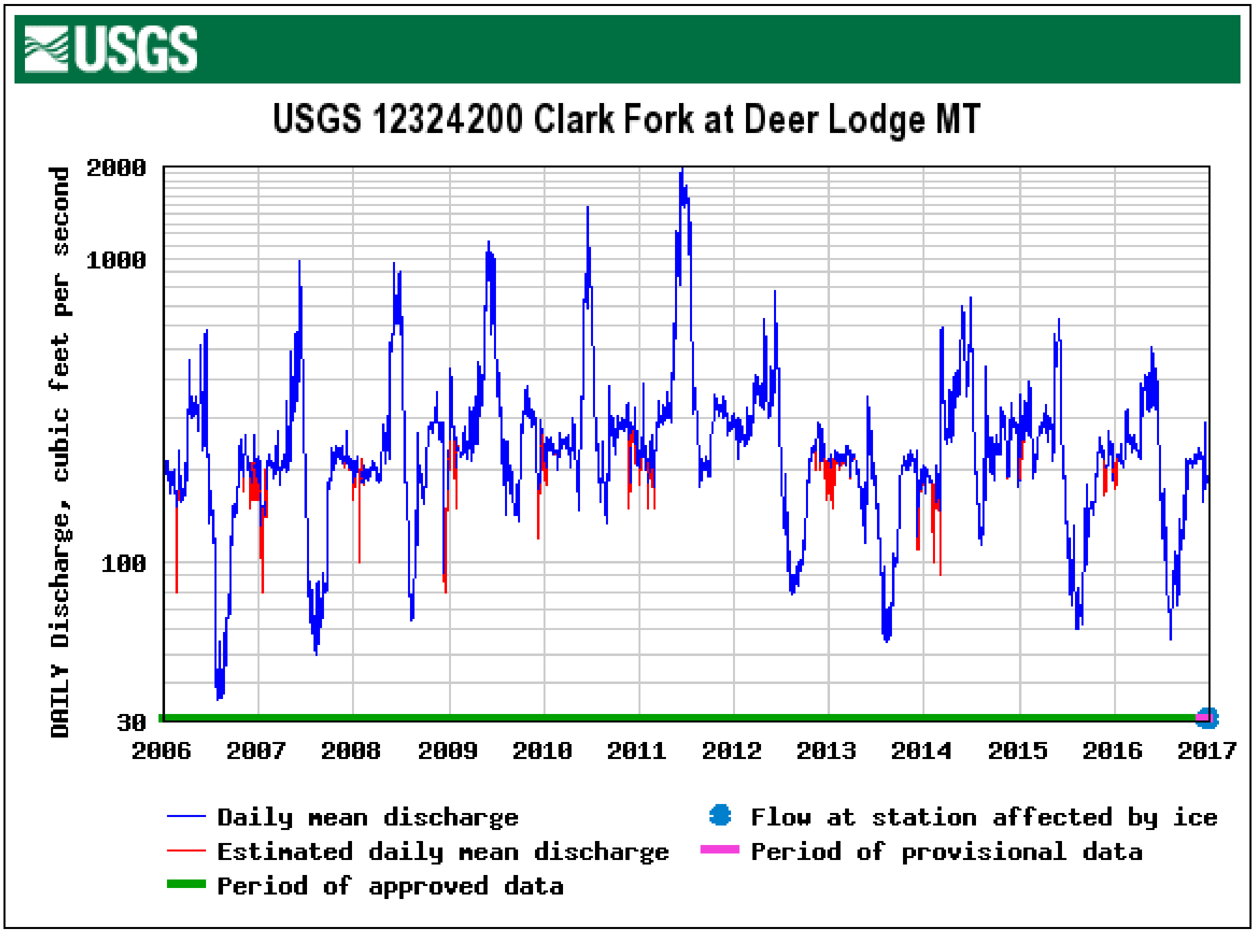

Figure 6-15. U.S. Geological Survey hydrograph from the Clark Fork River gage at Deer Lodge.

7.0 BIRDS[69]

7.1 INTRODUCTION

Bird species richness and abundance was monitored in the Clark Fork River Operable Unit (CFROU) from 2015-2017. Prior monitoring reports summarized annual monitoring data in 2015 and 2016. These reports are titled, September 1, 2015 DEQ – Clark Fork River Remediation Bird Surveys and September 1, 2016, Clark Fork River Remediation Bird Surveys. This report synthesizes results of those monitoring years as well as data collected during the 2017 field season to provide a complete assessment of all bird monitoring data in the CFROU to date. Special attention is paid to species richness and relative abundance by project phase and to the relative abundance of special status species in the CFROU. Results will provide valuable information to remedial design and construction teams to minimize disturbance of bird habitat and use of the CFROU during construction and revegetation activities and will provide an evaluation of the influence of the remedy on bird occupation and use of the CFROU following remediation.

7.2 METHODS

7.2.1 Monitoring Locations

Birds have been monitored in eight phases of the CFROU at 20 sites. In the first monitoring year (2015), three phases (Phases 1, 7, and 15) were monitored (Table 7-1) and remediation had just been completed in Phase 1, but no remediation had yet occurred in other phases. In 2016, six phases were monitored (Phases 1, 3, 4, 7, 8, and 15) (Table 7-1) and no additional phases monitored had been remedied. In 2017, monitoring occurred in seven phases (Phases 1, 2, 3, 4, 5, 6, 7, and 15) (Table 7-1) and remediation was completed in Phase 2 at that time.

Within each phase one to three sites were selected for monitoring. Each site was located within the riparian zone of the floodplain, near the river. Monitoring sites were located in habitats that were representative of a large proportion of the prevailing bird habitat within that phase. These sites will be resampled in future years unless access is restricted due to construction or other unforeseen factors.

In Phase 1 (60 acres), construction-related remedial actions were completed in the fall of 2014 and this was the first phase remediated in the CFROU. Revegetation actions continued into 2015. Phase 1 consists of 1.6 river miles. Several features adjacent to Phase 1 likely influence bird use within the phase. The Warm Springs Wildlife Management Area is located a short distance (approximately 1 mile) from the southern boundary of Phase 1. In addition, the confluence of

[69] Chapter 7 was completed by Gary Swant (GoBirdMontana) with editing and formatting by RESPEC.

Warm Springs Creek and Silver Bow Creek is located within the phase near the upstream (southern) boundary. Three sites have been monitored in Phase 1: sites 1-A, 1-B, and 1-C (Table 7-1). All three sites were monitored in 2015 but site 1-C was not monitored in 2016 and 2017. In 2016, remedial construction actions in Phase 2 would likely have inhibited bird use at site 1-C and therefore site 1-C was not monitored. Site 1-C was not monitored in 2017, as it was not monitored in 2016.

Phase 2 (88 acres) was under construction from the summer of 2015 through the fall of 2016. Phase 2 consists of 1.9 river miles immediately downstream from Phase 1. Two sites have been monitored in Phase 2: sites 2-A and 2-B (Table 7-1). Both sites were monitored for the first time in 2017 following completion of remedial activities.

Phases 3 and 4 (261 acres combined) were unremediated through the 2017 monitoring period. Combined these phases consist of 4.5 river miles and are located downstream from Phase 2. Three sites have been monitored in Phases 3 and 4: sites 3-A, 4-B, and 4-C (Table 7-1). Each of these sites was monitored in 2016 and 2017.

Remediation began in Phases 5 and 6 (125 acres combined) in the summer of 2014 and construction and revegetation actions were completed in 2016. Combined these phases consist of 4.3 river miles and are located immediately downstream from Phase 4. A feature adjacent to Phase 6, which may influence bird use within the phase, is the Racetrack Pond, located in Phase 7 immediately downstream. Three sites have been monitored in Phases 5 and 6: sites 5-A, 5-B, and 5-C (Table 7-1). Each of these sites was monitored for the first time in 2017 following completion of remedial activities.

Phase 7 (84 acres) had not been remediated as of 2017. This phase consists of a 1.9 river mile river reach located immediately downstream from Phase 6. Phase 7 is adjacent to the Racetrack Pond which likely strongly influences the bird assemblage and bird use of the phase. Another potential factor that may have influenced bird use of Phase 7 was the remedial actions in Phase 6 from 2014 through 2016. Three sites have been monitored in Phase 7: sites 7-A, 7-B, and 7-C (Table 7-1). Each of these sites was monitored in 2015 but only sites 7-A and 7-C were monitored in 2016 and 2017.

Phase 8 had not been remediated as of 2017. This phase is located immediately downstream from Phase 7. Phase 8 is located near the Racetrack Pond which may influence bird use. Three sites have been monitored in Phase 8: sites 8-A, 8-B, and 8-C (Table 7-1). Each site was monitored in 2016 but not in 2015 or 2017.

Phase 15 had not been remediated as of 2017. Phase 15 is located within the Grant-Kohrs National Historic Site just north of Deer Lodge. The Grant-Kohrs National Historic Site is a 1,600-acre cattle ranch maintained by the National Park Service. Three sites have been monitored in Phase 15: sites 15-A, 15-B, and 15-C (Table 7-1). Each site was monitored in 2015, 2016, and 2017.

Table 7-1. Bird monitoring site locations in the Clark Fork River Operable Unit, 2016.

Phase	Site	Latitude	Longitude	Year Monitored		
				2015	2016	2017
1	1-A	46.11"38.94	112.46'22.52""	X		
	1-B	46.11'38.09"	112.46'08.70"	X	X	X
	1-C	46.11'37.37"	112.35'35.19"	X	X	X
2	2-A	46.11'38.90"	112.46'34.56"			X
	2-B	46.11'46.03"	112.46'07.05"			X
3	3/4-A	46.12'58.01"	112.45'38.79"		X	X
4	3/4-B	46.13'32.73"	112.45'32.60"		X	X
	3/4-C	46.14'07.64"	112.45'12.63"		X	X
5	5/6-A	46.14'14.93"	112.45'16.71"			X
5	5/6-B	46.15'30.79"	112.45'08.29"			X
5	5/6-C	46.15'15.87"	112.45'14.68"			X
7	7-A	46.16'08.16"	112.44'34.67"	X	X	X
	7-B	46.16'29.23"	112.44'12.58"	X	X	X
	7-C	46.16'33.04"	112.43'57.66"	X		
8	8-A	46.17'21.14"	112.43'26.95"		X	
	8-B	46.17'27.56"	112.43'24.48"		X	
	8-C	46.17'33.39"	112.43'29.53"		X	
15	15-A	46.24'25.47"	112.44'55.93"	X	X	X
	15-B	46.24'34.85"	112.44'45.73"	X	X	X
	15-C	46.24'40.70"	112.44'46.57"	X	X	X

7.2.2 MonitoringSchedule

Bird monitoring has occurred in the CFROU in 2015, 2016, and 2017. Monitoring occurred during the spring and early summer during the months of April, May, and June. Each year, monitoring sites were visited approximately ten times during the three-month monitoring period. During each site visit, monitoring was conducted for 10 minutes. Sites within some phases have been visited more often than others (Table 7-2).

Table 7-2. Total number of site visits and number of monitoring sites within each phase for bird monitoring in the Clark Fork River Operable Unit, 2015-2017.

Phase	Sample Effort		
	Years Monitored	Sites	Site Visits (total)
1	2015-2017	2[70]	74
2	2017	2	16
3	2016, 2017	1	16
4	2016, 2017	2	38
5	2017	3	24
7	2015-2017	2[71]	76
8	2016	3	34
15	2015-2017	3	91

7.2.3 Monitoring Methods

All birds observed during each site visit were counted by species. In addition, the type of observation was distinguished to provide information about the certainty of the observation. Observations were separately classified as: 1) within a 40-m radius and identified by sight, 2) identified by call or song, 3) identified by sight flying within 40 m, 4) identified by sight flying outside or above 40 m, and 5) identified by sight at a distance greater than 40 m. Field parameters noted during each site visit included the time of the site visit, a description of weather, air temperature, and field notes.

7.2.4 Monitoring Methods

Each monitoring site was identified in the field with a site marker (i.e., white plastic tube). Counts were conducted after a two-minute period following the surveyor's arrival to allow birds to become accustomed to the surveyor's presence. Each bird observed was recorded using a 4-letter abbreviation commonly referred to as the "ALPHA" code [IBP, 2018].

7.2.5 Data Analysis

This report compares bird richness (i.e., species counts) and relative abundance (i.e., the count of observed individuals of a certain species in proportion to the count of observed individuals of

[70] One additional Phase 1 site (1-C) was monitored in 2015.

[71] One additional Phase 7 site (7-C) was monitored in 2015.

all species) among phases and summarizes richness in the CFROU throughout the monitoring period (2015-2017). All bird observations within each phase were pooled and variation due to sample site (within each phase), time period (including divergent years), and observation type (e.g., within 40 m or beyond 40 m) were ignored. This approach was taken because, at this point, monitoring is in the initial stages and only general conclusions are appropriate.

Bird species richness and relative abundance based on observations at all sample sites between 2015-2017 were tabulated by phase. Sampling effort (i.e. frequency of site visits) varied by phase which presents a confounding factor for comparisons between phases. For example, sites within Phase 1 have been visited 74 times compared to Phase 2 sites which have been visited 16 times (Table 7-2). Given this discrepancy in sampling effort between these phases, it is inappropriate to compare abundance of any bird species directly between these phases. We mitigated the confounding influence of sampling effort by comparing relative abundance on a “catch-per-unit-effort” (CPUE) scale rather than by direct comparisons of abundance. CPUE is an indirect measure of abundance and therefore variation in CPUE are not necessarily always representative of true differences in abundance but this measure provides the best possible means to compare relative abundance of these species by site or by phase. The CPUE metric compared in this report is the number of observations of a given species per site visit.

In addition to confounding comparisons of abundance, discrepancies in sampling effort also confound comparisons of species richness. Whereas, corrections can be made to abundance estimates fairly easily by converting to a relative abundance or CPUE-scale, comparing species richness is a bit more complicated. Species richness among phases was evaluated generally by plotting the species richness of each phase (y-axis) by the number of site visits (x-axis) and fitting a logarithmic curve to these data. The fitted logarithmic curve represents the “expected” species richness at any given level of effort (i.e., number of sample site visits). This method allows for general evaluation of the species richness of a given phase against the “expected” species richness given results in all phases.

Results are summarized for each species by phase, by taxonomic order, and for each “Species of Concern” [MNHP, 2017].

7.3 RESULTS

7.3.1 Results by Phase

Bird diversity in the CFROU is high. Since 2015, 114 separate bird species have been identified in the CFROU (Table 7-3). Based on the monitoring data since 2015, the taxonomic orders with the highest species richness included: perching birds (Passeriformes; 45 species), waterfowl (Anseriformes; 23 species), shorebirds, waders and gulls (Charadriiformes; 13 species), and birds of prey (Accipitriformes; 8 species).

As expected, given the variability in the sampling effort by phase, species richness has varied in the CFROU. The highest number of species observed since 2015 has been in Phase 7 (79 species) followed, in order, by Phase 15 (75 species), Phase 4 (65 species), Phase 1 (63 species), Phase 8 (52 species), Phase 5 (44 species), Phase 3 (41 species), and Phase 2 (34 species) (Table 7-3).

Despite the wide variation among phases in sampling effort species richness among phases was quite similar. Species richness generally increased with the frequency of site visits in each phase but appeared to approach an asymptotic limit (Figure 7-1). The relationship between site visits per phase and species richness was modeled well by the logarithmic curve (r^2 = 0.8812). Generally, the species richness observed to date in each phase was what would be expected given the level of sampling effort in those phases suggesting species richness among phases is relatively similar. Small differences were apparent however from the relationship. Phases 4 and 7 stood out as having a bit higher species richness than expected and Phase 1 stood out slightly as having a bit lower species richness than expected (Figure 7-1).

Table 7-3. Occurrence and estimated abundance of bird species in the Clark Fork River Operable Unit by phase, 2015-2017. Symbols for estimates of abundance are: * = rare, ** = common, and * = abundant.**

Order	Family	Species	Phase							
			1	2	3	4	5	7	8	15
Birds of Prey (Accipitriformes)	Hawks and Eagles (Accipitridae)	Bald Eagle	*		**	*	*	*	*	*
		Cooper's Hawk							*	
		Golden Eagle			*					
		Northern Harrier	**			*				*
		Red-tailed Hawk	*		*	**		*		**
		Sharp-shinned Hawk	*							*
		Swainson's Hawk			*	*		*	*	
	Osprey (Pandionidae)	Osprey	*	**	**	**		**	**	*

Order	Family	Species	Phase							
			1	2	3	4	5	7	8	15
Waterfowl (Anseriformes)	Ducks, Geese and Swans (Anatidae)	American Wigeon		**	**		**	**		**
		Barrow's Goldeneye	*	**				*	**	*
		Bufflehead	*					*		*
		Blue-winged Teal						*		*
		Canada Goose	***		***	**		***	***	***
		Canvasback		**						
		Cinnamon Teal	*	*		*		**	*	**
		Common Goldeneye	**	***		*	**	**	*	*
		Common Merganser	*			*	*	**	*	**
		Gadwall	**	**			*	**		**
		Green-winged Teal	*	**			*	**	*	**
		Hooded Merganser						**		*
		Lesser Scaup	**			*	**	**		**
		Mallard	***	***	***	***	***	***	***	***
		Northern Pintail				**	**			*
		Northern Shoveler	**	**			*	**		*
		Red-breasted Merganser						**		*
		Redhead		*				*		
		Ring-necked Duck						*		*
		Ross's Goose			**	*	**	*		
		Ruddy Duck					**	***		
		Snow Goose				**	***	*		
		Trumpeter Swan								*
Nighthawks (Caprimulgiformes)	Nighthawks (Caprimulgidae)	Common Nighthawk				*				*
New World Vultures (Cathartiformes)	New World vultures (Cathartidae)	Turkey Vulture	*	*		*		*	*	
Shorebirds and Waders (Charadriiformes)	Killdeer (Charadriidae)	Killdeer	**	**	*	**	**	**	**	**
	Gulls, Terns and Skimmers (Laridae)	Bonaparte's Gull	*							
		California Gull	***	***	***	***	***	***		**
		Forster's Tern				*				
		Franklin's Gull	*							
		Ring-billed Gull	***	****	**	**	**	***	**	**
	Avocets (Recurvirostridae)	American Avocet	**	**	*			**		
		Greater Yellowlegs						*		

Order	Family	Species	Phase							
			1	2	3	4	5	7	8	15
	Waders (Scolopacidae)	Long-billed Curlew			**					
		Lesser Yellowlegs					*			
		Solitary Sandpiper				*		*		
		Spotted Sandpiper	**			**	**	**	**	*
		Wilson's Snipe	*	**		*		*	*	**
Pigeons and Doves (Columbiformes)	Pigeons and Doves (Columbidae)	Eurasian Collared-Dove							**	
		Mourning Dove	**	**	*	**	**	**	**	**
		Rock Pigeon			**	**			*	**
Kingfishers (Coraciiformes)	Kingfishers (Alcedinidae)	Belted Kingfisher	*			*			*	
Falcons and Kestrels (Falconiformes)	Falcons (Falconidae)	American Kestrel	*			*	*	*	*	*
		Merlin				*				
		Peregrine Falcon		*						
Gamefowl (Galliformes)	Gamefowl (Phasianidae)	Gray Partridge				*	*			
Loons (Gaviiformes)	Loons (Gaviidae)	Common Loon						*		
Cranes and Rails Gruiformes)	Cranes (Gruidae)	Sandhill Crane	*	**		*	*	*	**	**
	Rails (Rallidae)	American Coot	**			*		**		**
							**			
		Sora								*
Perching Birds (Passeriformes)	Waxwings (Bombycillidae)	Cedar Waxwing	*						*	
	Cardinals (Cardinalidae)	Black-headed Grosbeak								*
	Jays, Crows, and Magpies (Corvidae)	American Crow	*	**			*	*	*	*
		Black-billed Magpie	***	***	**	**	**	**	***	***
		Common Raven	**	***	***	**	**	**	**	**
	New World Sparrows (Passerellidae)	American Tree Sparrow	*							*
		Clay-colored Sparrow	**	**	**	**		*	*	*
		Fox Sparrow				*				
		Lark Sparrow						*		
		Savannah Sparrow	**	**	**	**	**	**	**	**
		Vesper Sparrow	*		*	*	**	*	**	*
		White-crowned Sparrow								*
	Finches (Fringillidae)	American Goldfinch						*		

Order	Family	Species	Phase 1	2	3	4	5	7	8	15
	Swallows (Hirundinidae)	Bank Swallow	*		**	*		**	***	**
		Barn Swallow			*	*	**	**		*
		Cliff Swallow	*		***	***	*	**	**	*
		Northern Rough-winged Swallow	*		*	*	**	**		**
		Tree Swallow	***	**	***	***	***	***	***	***
		Violet-green Swallow				**	*	*		
	Blackbirds (Icteridae)	Brown-headed Cowbird	***	*	**	***	**	***	**	**
		Bobolink						*		**
		Brewer's Blackbird	**	**	**	**	**	**	**	**
		Bullock's Oriole	*						*	*
		Common Grackle				*	*	*	*	*
		Red-winged Blackbird	***		**	**	**	***	**	**
		Western Meadowlark	**	*	**	**	**	**	***	***
		Yellow-headed Blackbird	***	**		**		*		*
	Thrashers, Mockingbirds, and Catbirds (Mimidae)	Gray Catbird	*			*	*	**		*
	Chickadees (Paridae)	Black-capped Chickadee	*			*		**	*	**
	Warblers (Parulidae)	Common Yellowthroat	*							*
		Northern Waterthrush	*							
		Orange-crowned Warbler						*		
		Yellow Warbler			**	**		*	**	**
		Yellow-rumped Warbler			*	*		*	*	*
	New World Sparrows (Passerellidae)	Song Sparrow	**	*	**	**	*	**	*	**
	Kinglets (Regulidae)	Ruby-crowned Kinglet								*
	Starlings (Sturnidae)	European Starling	**		**	**	***	**	***	**
	Wrens (Troglodytidae)	House Wren							*	*
		Marsh Wren	*							*
	Thrushes (Turdidae)	American Robin	*		**	**	**	**	**	**
		Mountain Bluebird	*			*		**	*	
		Swainson's Thrush						*		

Order	Family	Species	Phase							
			1	2	3	4	5	7	8	15
	Flycatchers (Tyrannidae)	Eastern Kingbird	*		**	**	**	**	**	**
		Least Flycatcher						*	*	
		Willow Flycatcher			**	**		**		*
Pelicans, Herons, and Ibises (Pelecaniformes)	Herons (Ardeidae)	Great Blue Heron	**		*	*	*	*	*	*
	Pelicans (Pelecanidae)	American White Pelican	*	**	**	*		**	*	*
	Ibises and Spoonbills (Threskiornithidae)	White-faced Ibis				*				
Woodpeckers (Piciformes)	Woodpeckers (Picidae)	Downy Woodpecker								*
		Northern Flicker	*		**	*		**	**	**
		Red-naped Sapsucker	*							
Grebes (Podicipediformes)	Grebes (Podicipedidae)	Horned Grebe						*		
		Red-necked Grebe		*				*		
		Western Grebe						*		
Owls (Strigiformes)	Owls (Strigidae)	Great Horned Owl				*				
Cormorants (Suliformes)	Cormorants and Shags (Phalacrocoracidae)	Double-crested Cormorant	**	**	***	**	**	**	**	*
Total (Species)			**63**	**34**	**41**	**65**	**44**	**79**	**52**	**75**

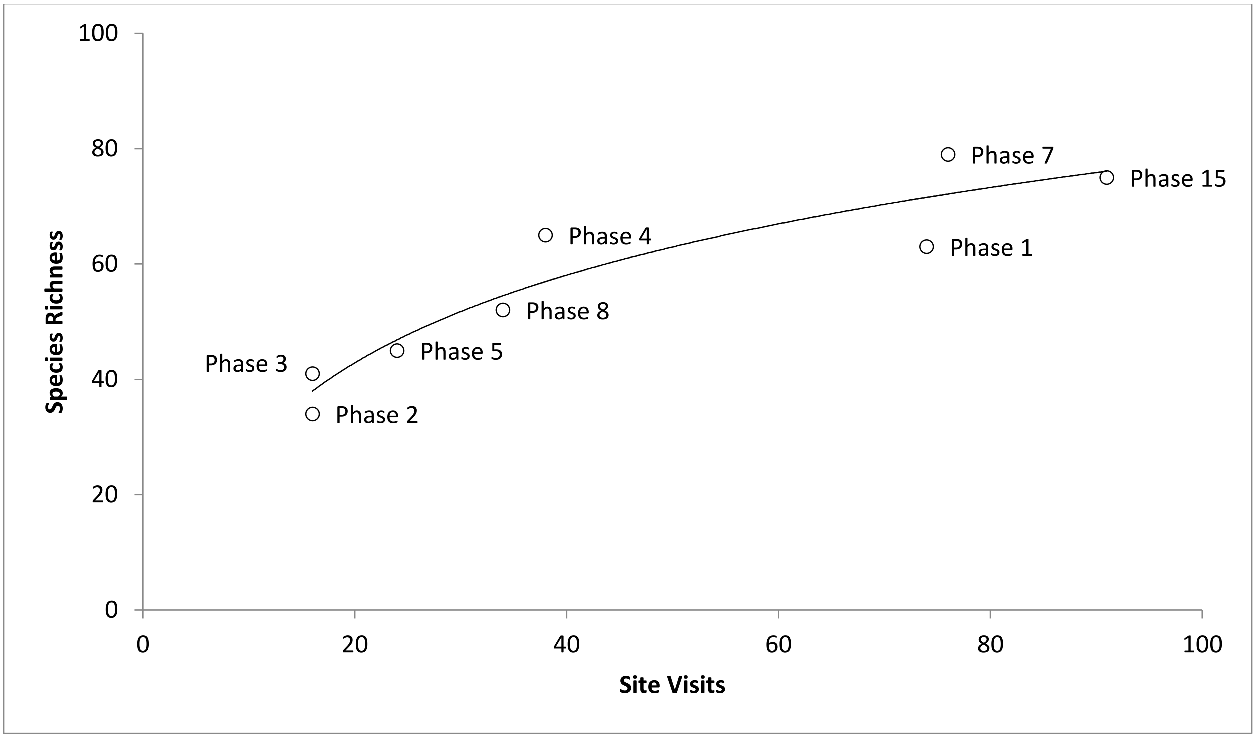

Figure 7-1. Species richness by frequency of site visits for each phase sampled in the Clark Fork River Operable Unit, 2015-2017.

7.3.2 Results by Taxonomic Order

7.3.2.1 Birds of Prey

Birds of prey (Accipitriformes) were generally common in the CFROU and species richness for this taxonomic order was high overall (Table 7-1). Relative abundance of birds of prey overall was highest in Phase 7 and lowest in Phases 2 and 5 (Figure 7-2). The particular assemblage of birds of prey in each phase was generally unique (Figure 7-2).

Two observed birds of prey, both eagle species, have special status designations in Montana. Bald eagles *Haliaeetus leucocephalus* are, "Special status species because, although it is no longer protected under the Endangered Species Act and is also no longer a Montana Species of Concern, it is still protected under the Bald and Golden Eagle Protection Act of 1940 (16 U.S.C. 668-668c)" [MNHP, 2017]. Bald eagles were observed in all phases except Phase 2 (Figure 7-2). Golden eagles *Aquila chrysaetos*, in addition to having protection under the Bald and Golden Eagle Protection Act of 1940, are a Species of Concern because breeding populations in the state are "potentially at risk", although globally the species is considered to be "common" [MNHP, 2017]. Only one individual golden eagle has been observed and that individual was observed passing through the sample site (Phase 3).

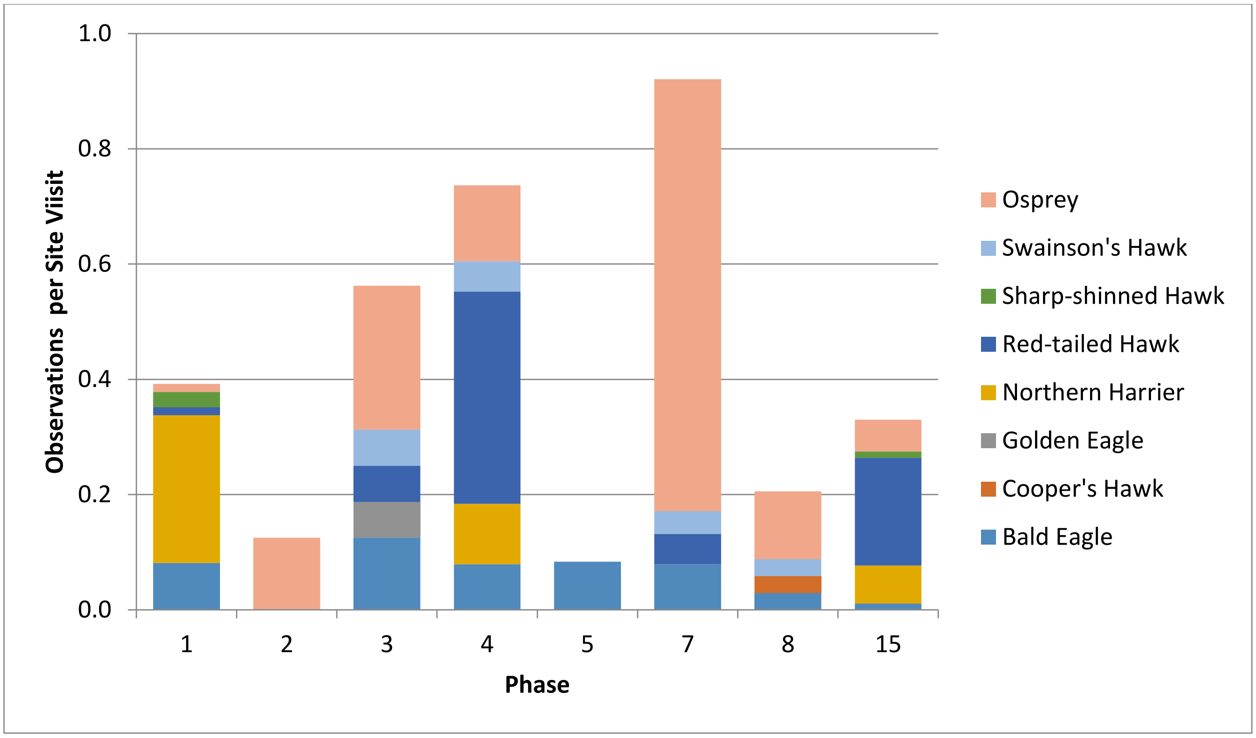

Figure 7-2. Relative abundance of birds of prey (Acciptriformes) by phase in the Clark Fork River Operable Unit, 2015-2017.

7.3.2.2 Waterfowl

Waterfowl (Anseriformes) diversity in the CFROU was high, particularly in Phase 7 (Table 7-3). Relative abundance of waterfowl was nearly twice as high in Phase 7 compared to all other phases (Figure 7-3). Other phases had similar waterfowl relative abundance overall, although Phases 4 and 8 were relatively low (Figure 7-3). Phase 3, which had the second highest waterfowl relative abundance, had the lowest species richness and the waterfowl assemblage 3 was dominated by Canada goose *Branta canadensis* and mallards *Anas platyrhynchos* (Figure 7-3).

One observed waterfowl species is a Species of Concern in Montana: trumpeter swan *Cygnus buccinator* [MNHP, 2017]. Trumpeter swan populations are noted by MNHP [2017] globally to be “apparently secure” but within the state of Montana are considered to be “potentially at risk”. Four trumpeter swans were observed in Phase 15 at one sample site (Site 15-A) on April 5, 2016. Two observed species are “potential species of concern”: Barrow's goldeneye *Bucephala islandica* and hooded merganser *Lophodytes cucullatus* [MNHP, 2017]. Barrow’s goldeneye was observed in five phases (Phases 1, 2, 7, 8, and 15) and were common in Phases 2 and 8 (Figure 7-3). Hooded mergansers were identified in 2 phases (Phases 7 and 15) and were common in Phase 7 (Figure 7-3).

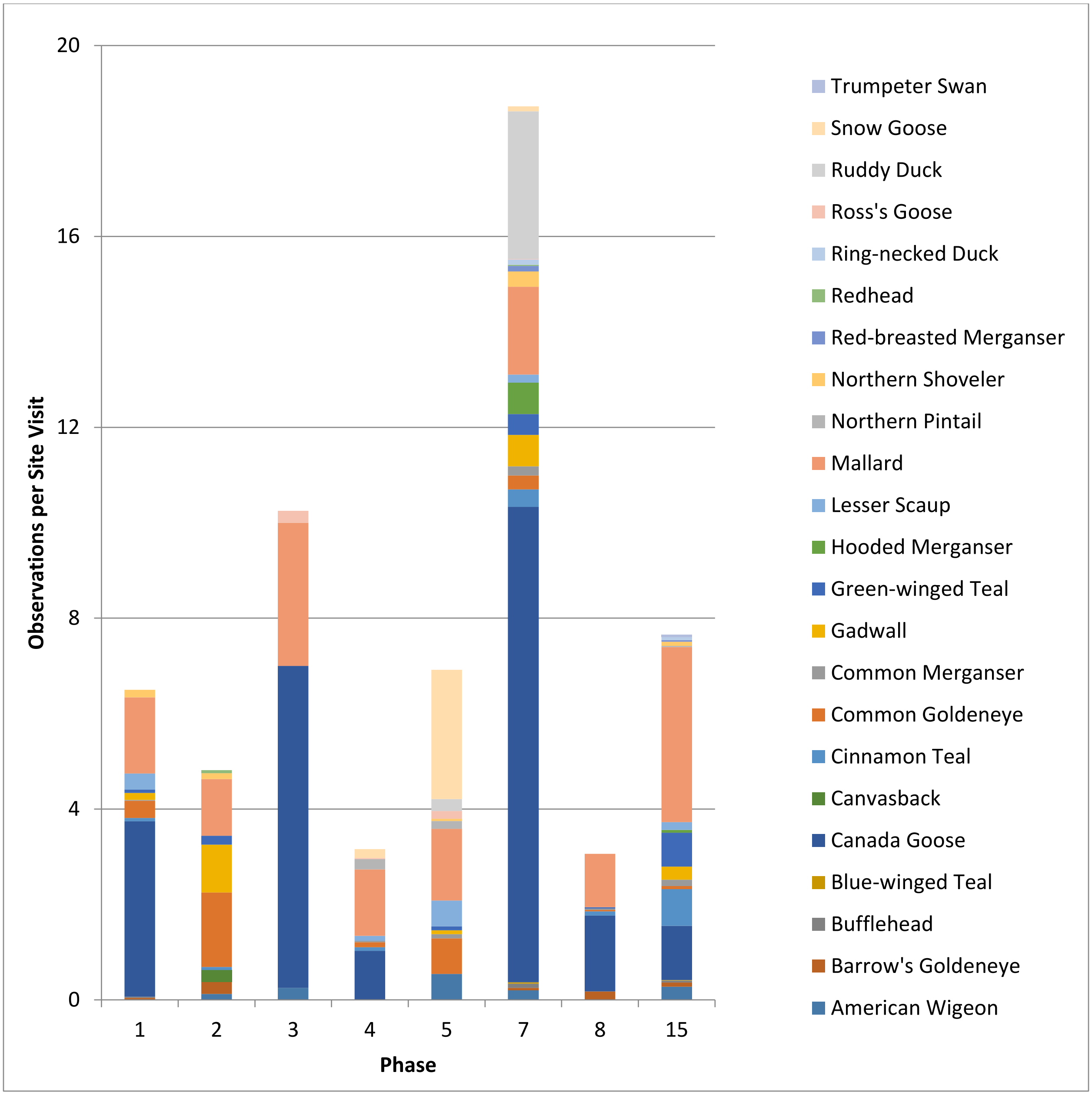

Figure 7-3. Relative abundance of waterfowl (Anseriformes) by phase in the Clark Fork River Operable Unit, 2015-2017.

7.3.2.3 Nighthawks

One nighthawk (Caprimulgiformes) species was observed in the CFROU: common nighthawk *Chordeiles minor*. Since 2015, common nighthawks have only been observed in Phases 4 and 15 and the frequency of these observations have been rare (Table 7-3). This species is common throughout Montana and most of the contiguous United States [MNHP, 2017].

7.3.2.4 New World Vultures

One vulture (Cathartiformes) species was observed in the CFROU: turkey vulture *Cathartes aura*. Turkey vulture observations were rare although the species has been observed in all phases except Phases 3, 5, and 15 (Table 7-3). This species is very common in some portions of the contiguous U.S., although breeding populations in Montana are somewhat scarce [MNHP, 2017]. Montana is located near the northern portion of this species' range [MNHP, 2017].

7.3.2.5 Shorebirds and Waders

Shorebirds and wader (Charadriiformes) species were well-represented in the CFROU with twelve species observed including representatives of four families: killdeer (Charadriidae); gulls, terns and skimmers (Laridae); avocets (Recurvirostridae); and waders (Scolopacidae) (Table 7-3).

Killdeer *Charadrius vociferus*, the only observed member of the Charadriidae family, were observed in all phases and were generally common, particularly in Phase 1 (Figure 7-4). Killdeer are considered common in Montana [MNHP, 2017].

Five species in the Laridae family were observed: Bonaparte's Gull *Chroicocephalus philadelphi*a, California gull *Larus californicus*, Forster's tern *Sterna forsteri*, Franklin's gull *Leucophaeus pipixcan*, and ring-billed gull *Larus delawarensis*. Bonaparte's gull, a nonnative species to Montana [MNHP, 2017], were rare and only observed in Phase 1 (Figure 7-4). California gulls and ring-billed gulls were observed in all phases and were abundant particularly in Phases 1, 2 and 7 (Figure 7-4). Overall, California gulls and ring-billed gulls were the dominant shorebird and wader species in the CFROU (Figure 7-4). California gulls were generally more evenly distributed across CFROU phases compared to ring-billed gulls, which were especially abundant in Phase 2 (Figure 7-4). Two Laridae species (Forster's tern Franklin's gull), observed in the CFROU are considered Montana Species of Concern because breeding populations in the state are potentially at risk, although populations of both are considered globally secure [MNHP, 2017]. Both species were rare in the CFROU. Forster's tern has only been observed in Phase 4 and Franklin's gull has only been observed in Phase 1 (Figure 7-4).

American avocet *Recurvirostra americana*, the only observed member of the Recurvirostridae family, were observed in four phases (1, 2, 3, and 7) and were common in Phases 1 and 7 (Figure 7-4). American avocet breeding populations are considered "apparently secure" in Montana and common globally [MNHP, 2017].

Six shorebird species in the Scolopacidae family were observed: greater yellowlegs *Tringa melanoleuca,* long-billed curlew *Numenius americanus,* lesser yellowlegs *Tringa flavipes,* solitary sandpiper *Tringa solitaria,* spotted sandpiper *Actitis macularius,* and Wilson's snipe *Gallinago delicata*. Spotted sandpipers were relatively common, particularly in Phases 1, 5, 7, and 8 (Figure

7-4). Wilson's snipe were observed in every phase except Phases 3 and 5 (Figure 7-4). One Scolopacidae species (long-billed curlew) observed in the CFROU is considered a Montana Species of Concern because breeding populations in the state are potentially at risk, although populations are considered globally secure [MNHP, 2017]. Long-billed curlew were observed in Phase 3 (Figure 7-4).

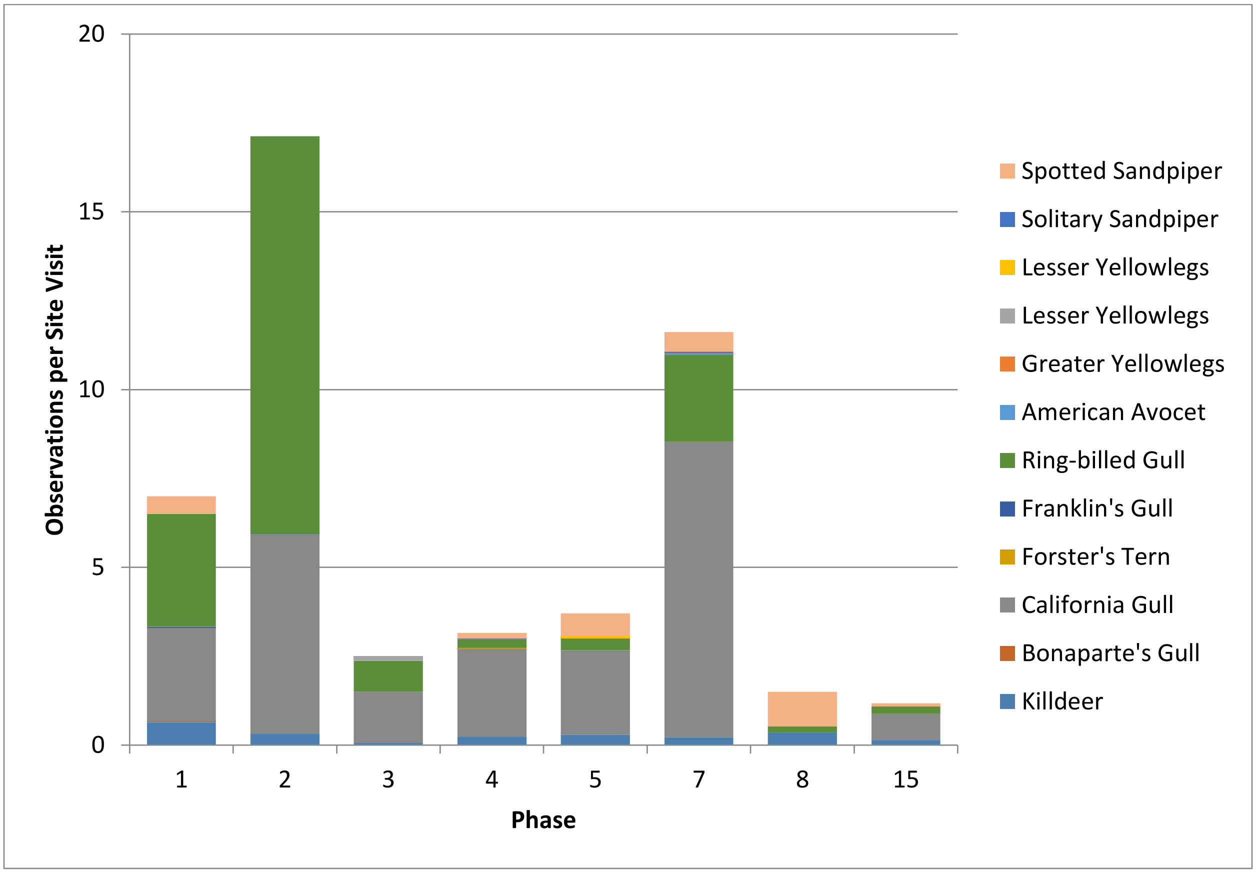

Figure 7-4. Relative abundance of shorebirds and waders (Charadriiformes) by phase in the Clark Fork River Operable Unit, 2015-2017.

7.3.2.6 Pigeons and Doves

Three pigeon and dove species (Columbiformes) were observed in the CFROU: Eurasian collared-dove *Streptopelia decaocto*, mourning dove *Zenaida macroura*, and rock pigeon *Columba livia*. Only one of those species (mourning dove) is native to Montana [MNHP, 2017]. Mourning doves were the most widespread of these species, but rock pigeon were common in most phases where they occurred, particularly Phase 3 (Figure 7-5). Eurasian collared-dove have only been observed in Phase 8 (Figure 7-5).

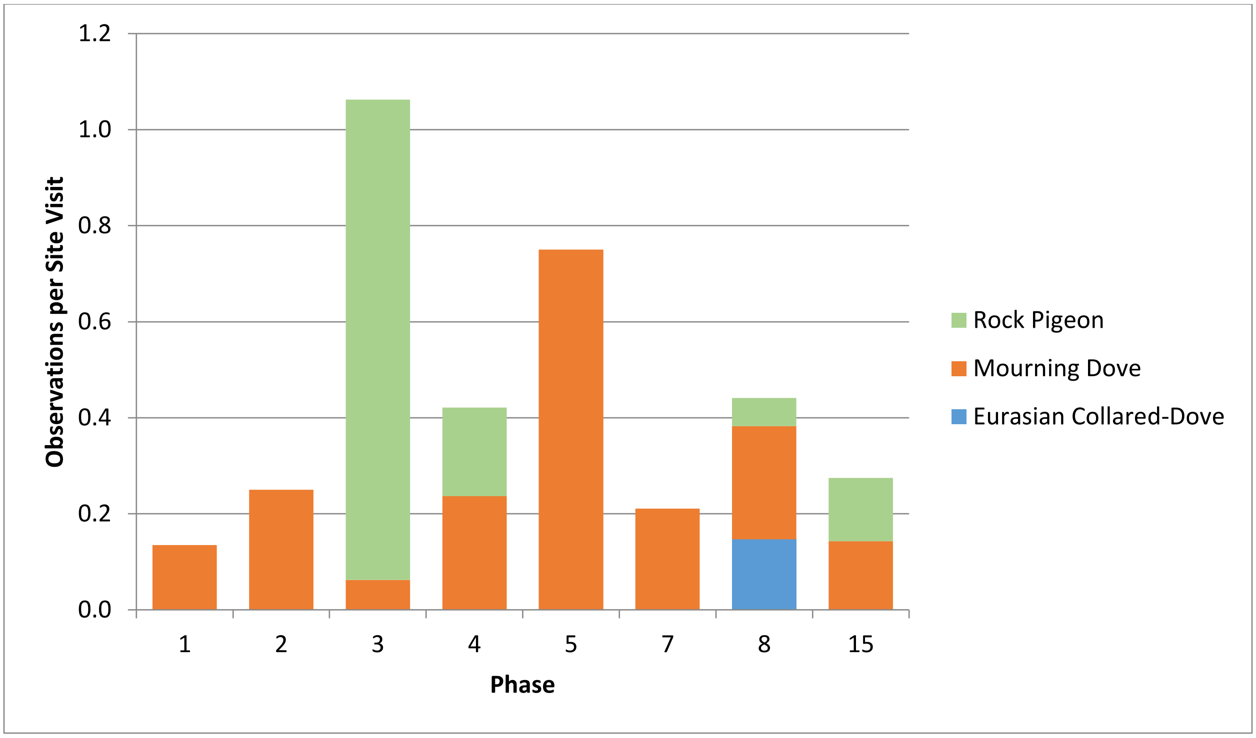

Figure 7-5. Relative abundance of pigeon and dove species (Columbiformes) by phase in the Clark Fork River Operable Unit, 2015-2017.

7.3.2.7 Kingfishers

One kingfisher (Coraciiformes) species was observed in the CFROU: belted kingfisher *Megaceryle alcyon*. Belted kingfisher observations in the CFROU have been rare and the species has only been observed in Phases 1, 4, and 15 (Table 7-1) although this species is common in Montana and other portions of the U.S. [MNHP, 2017].

7.3.2.8 Falcons and Kestrels

Three falcons (Falconiformes) were observed in the CFROU: American kestrel *Falco sparverius,* merlin *Falco columbarius*, and peregrine falcon *Falco peregrinus*. Peregrine falcons are a Species of Concern in Montana although globally populations are considered "apparently secure" [MNHP, 2017]. Merlin populations are considered somewhat at risk ("apparently secure") in Montana but common globally [MNHP, 2017]. Observations in the CFROU of those species support those designations. Both species have only been rarely observed and were not widely distributed among phases (Table 7-1). American kestrel were also generally rare but were widely distributed and observed in all but two phases (Table 7-1).

7.3.2.9 Gamefowl

One upland game bird (Galliformes) species was observed in the CFROU: gray partridge *Perdix perdix*. Gray partridge are a nonnative species [MNHP, 2017] and have only scarcely been observed in the CFROU (Table 7-1).

7.3.2.10 Loons

One loon (Gaviiformes) species was observed in the CFROU: common loon *Gavia immer*. Breeding populations of common loons are potentially at risk and the species is listed as a Species of Concern in Montana, although globally the species is considered common [MNHP, 2017]. Montana is at the southern end of this species' breeding range. Common loons have only been observed in Phase 7 and were rare (Table 7-1).

7.3.2.11 Cranes and Rails

Cranes and rails (Gruiformes) were represented in two families in the CFROU: cranes (Gruidae) and rails (Rallidae). One crane species was observed (sandhill crane *Antigone canadensis*) and two rails (American coot *Fulica americana* and sora *Porzana carolina*).

Sandhill cranes were observed in all phases, except Phase 3, and were common in Phases 2, 8, and 15 (Figure 7-6). Breeding Sandhill Crane Populations are common but overwintering populations in the state are "at risk" [MNHP, 2017].

Of the two rail species observed, American coots were most abundant and widely distributed (Figure 7-6). Sora were only observed in Phase 5 (Figure 7-6).

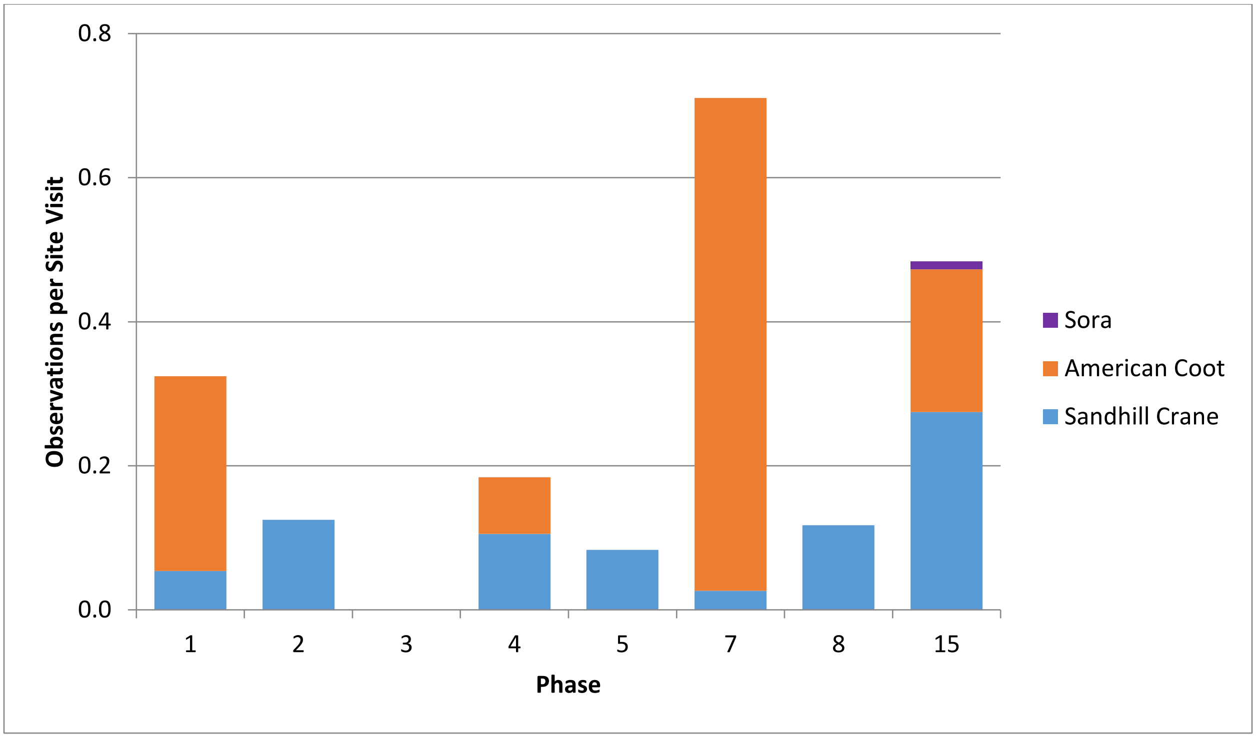

Figure 7-6. Relative abundance of crane-like species (Gruiformes) by phase in the Clark Fork River Operable Unit, 2015-2017.

7.3.2.12 Perching Birds

Of all taxonomic orders, perching birds (Passeriformes) were the richest in the CFROU from 2015-2017. In total, 39 passerine species from 16 distinct families were observed. Families identified in the CFROU to date include: waxwings (Bombycillidae); tanagers, cardinals, and buntings (Cardinalidae); jays, crows and magpies (Corvidae); New World sparrows (Passerellidae); finches (Fringillidae); swallows (Hirundinidae); blackbirds (Icteridae); thrashers, mockingbirds, and catbirds (Mimidae); chickadees (Paridae); warblers (Parulidae); Old World sparrows (Passeridae); kinglets (Regulidae); starlings (Sturnidae); wrens (Troglidytidae); thrushes (Turdidae); and flycatchers (Tyrannidae).

Eight species were identified in the CFROU which were the only familial representative: cedar waxwing *Bombycilla cedrorum* (Bombycillidae), black-headed grosbeak *Pheucticus melanocephalus* (Cardinalidae), American goldfinch *Spinus tristis* (Fringillidae), gray catbird *Dumetella carolinensis* (Mimidae), black-capped chickadee *Poecile atricapillus* (Paridae), song sparrow *Melospiza melodia* (Passerellidae), ruby-crowned kinglet *Regulus calendula* (Regulidae), and European starling *Sturnus vulgaris* (Sturnidae) (Figure 7-7). Of these species, European starling, a nonnative species, were most abundant (Figure 7-7).

Corvids were represented by three species: American crow *Corvus brachyrhynchos,* black-billed magpie *Pica hudsonia*, and common raven *Corvus corax* (Figure 7-8). Ravens and magpies were abundant throughout the CFROU (Figure 7-8). American crows were relatively scarce compared to magpies and ravens (Figure 7-8).

Passerellids was represented by seven species: American tree sparrow *Spizelloides arborea,* clay-colored sparrow *Spizella pallida,* fox sparrow *Passerella iliaca,* lark sparrow *Chondestes grammacus,* savannah sparrow *Passerculus sandwichensis,* vesper sparrow *Pooecetes gramineus,* and white-crowned sparrow *Zonotrichia leucophrys* (Figure 7-9). Vesper, savannah, and clay-colored sparrows were common and ubiquitous in the CFROU (Figure 7-9). American tree sparrows, fox sparrows, lark sparrows and white-crowned sparrows were rare and occurred sporadically (Figure 7-9).

Six hiruninids were observed in the CFROU: bank swallow *Riparia riparia*, barn swallow *Hirundo rustica*, cliff swallow *Petrochelidon pyrrhonota*, northern rough-winged swallow *Stelgidopteryx serripennis*, tree swallow *Tachycineta bicolor*, and violet-green swallow *Tachycineta thalassina* (Figure 7-10). The three dominant hiruninids were tree swallows, cliff swallows, and bank swallows. Tree swallows were generally very abundant in all phases (Figure 7-10). Cliff swallows were abundant in Phases 3, 4, and 8 but were generally absent or rare in other phases (Figure 7-10). Bank swallows were abundant in Phase 8 but were less abundant in other phases (Figure 7-10). Barn swallows, northern rough-winged swallows, and violet-green swallow were generally rare and occurred sporadically (Figure 7-10).

Icterids were a rich family represented in the CFROU by brown-headed cowbird *Molothrus ater*, bobolink *Dolichonyx oryzivorus,* Brewer's blackbird *Euphagus cyanocephalus,* Bullock's oriole *Icterus bullockii,* common grackle *Quiscalus quiscula,* red-winged blackbird *Agelaius phoeniceus,* western meadowlark *Sturnella neglecta*, and yellow-headed blackbird *Xanthocephalus xanthocephalus* (Figure 7-11). These species were generally common to abundant and ubiquitous in the CFROU with a couple exceptions (Figure 7-11). Bobolink, a Montana Species of Concern, were observed only in Phase 7 (one observation) and Phase 15 where they were common (Figure 7-11). This species has declined in abundance in Montana which has led to the special status designation [MNHP, 2017]. The decline in bobolink in Montana is due to loss or degradation of meadows and hay fields which are the primary breeding habitat for the species [MNHP, 2017]. Bullock's oriole were also rare in the CFROU (Figure 7-11).

Parulids were also a well represented family in the CFROU with five species observed: common yellowthroat *Geothlypis trichas,* northern waterthrush *Parkesia noveboracensis,* orange-crowned warbler *Oreothlypis celata,* yellow warbler *Setophaga petechial,* and yellow-rumped warbler *Setophaga coronate* (Figure 7-12). These species were not abundant and no parulids were observed Phases 2 and 5 (Figure 7-12). Yellow warblers were the only common parulid in the CFROU (Figure 7-12). Northern waterthrush, orange-crowned warblers, and common yellowthroat were rarely observed and only in Phases 1, 7, or 15 (Figure 7-12).

Two troglidytids were observed in the CFROU: house wren *Troglodytes aedon* and marsh wren *Cistothorus palustris* (Figure 7-13). Both were rare and were observed only in Phases 1, 8, or 15 (Figure 7-13).

Turdids were represented by three species in the CFROU: American robin *Turdus migratorius*, mountain bluebird *Sialia currucoides*, and Swainson's thrush *Catharus ustulatus* (Figure 7-13). American robin were generally common and widespread although none have yet been observed in Phase 2 (Figure 7-13). Swainson's thrush were rare and only observed in Phase 7 (Figure 7-13). Mountain bluebird were common in Phase 7 but either rare or absent in other phases (Figure 7-13).

Tyrannids were represented by three species in the CFROU: eastern kingbird *Tyrannus tyrannus*, least flycatcher *Empidonax minimus*, and willow flycatcher *Empidonax traillii* (Figure 7-14). Eastern kingbird were common in most phases and willow flycatchers were common in Phases 3, 4, and 7 but were rare or absent outside those phases (Figure 7-14). Least flycatchers were rare and were only observed in Phases 7 and 8 (Figure 7-14).

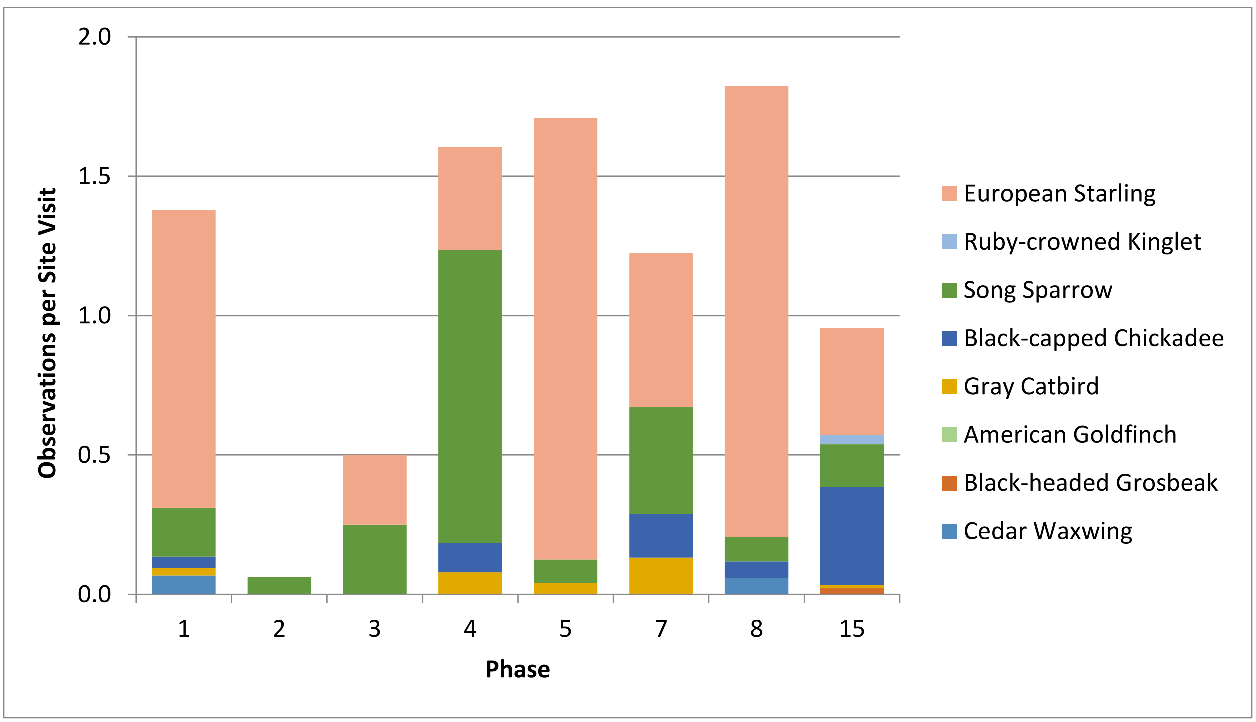

Figure 7-7. Relative abundance of passerines, which were the only observed familial representative, by phase in the Clark Fork River Operable Unit, 2015-2017.

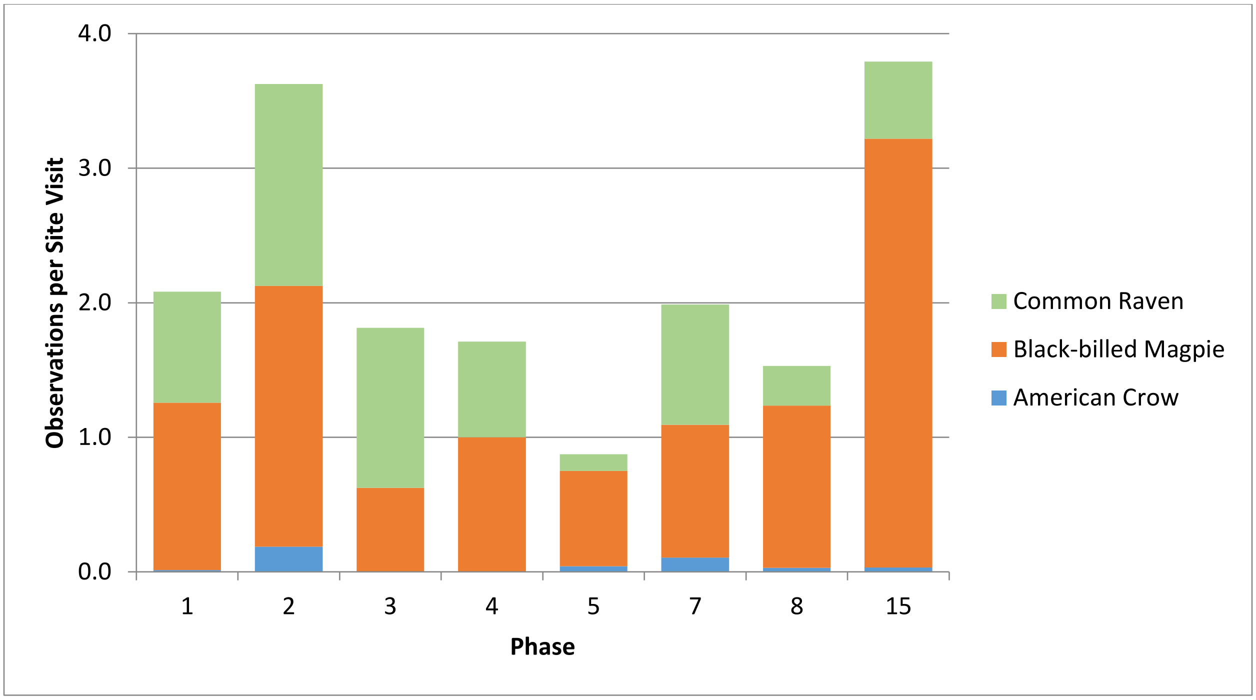

Figure 7-8. Relative abundance of jays, crows, and magpies (Corvidae) by phase in the Clark Fork River Operable Unit, 2015-2017.

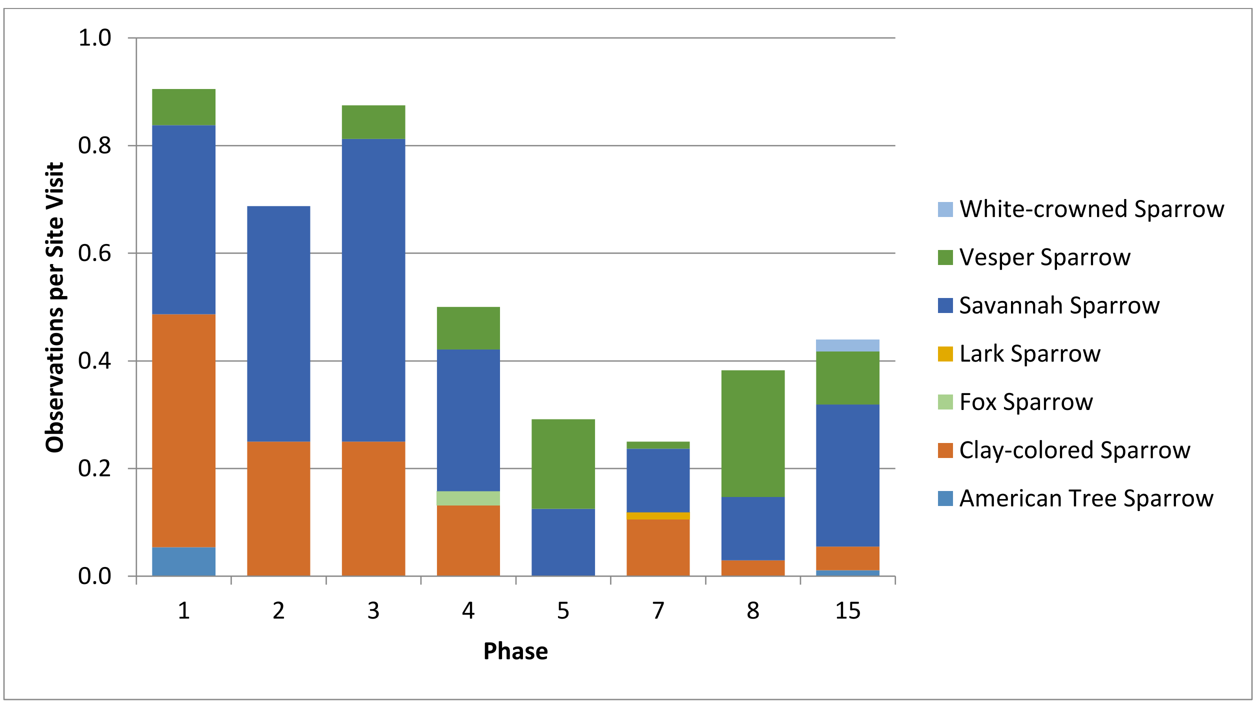

Figure 7-9. Relative abundance of new world sparrows (Passerellidae) by phase in the Clark Fork River Operable Unit, 2015-2017.

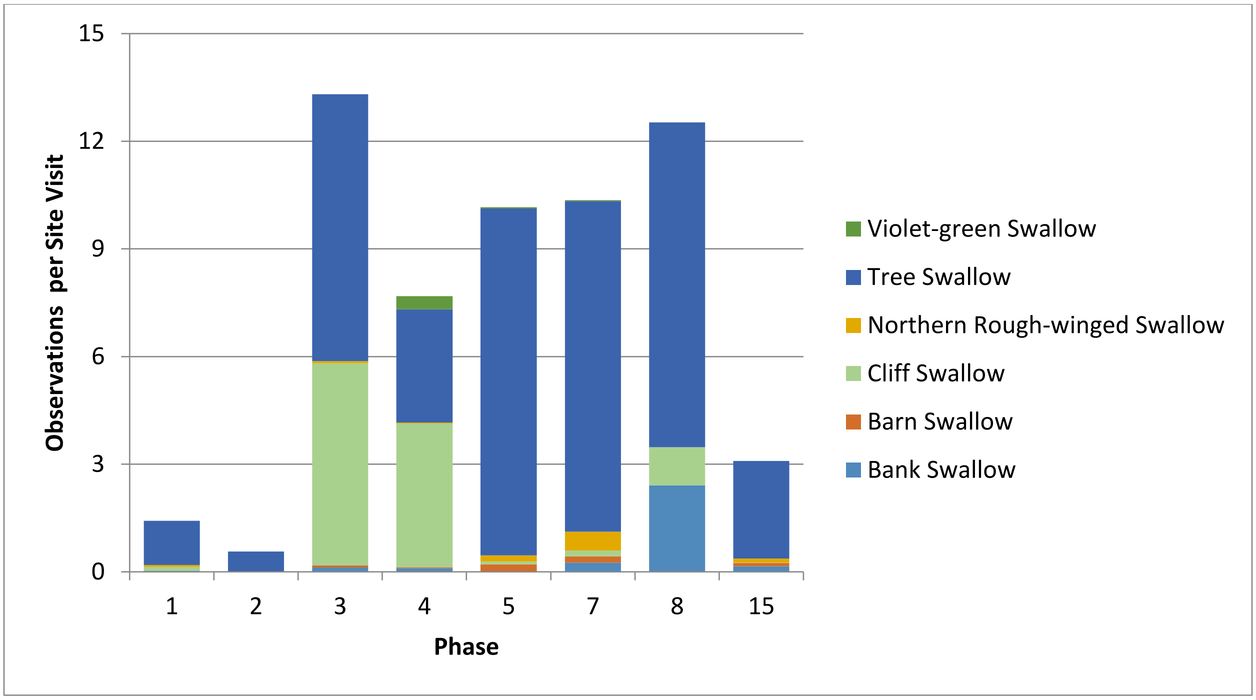

Figure 7-10. Relative abundance of swallows (Hirundinidae) by phase in the Clark Fork River Operable Unit, 2015-2017.

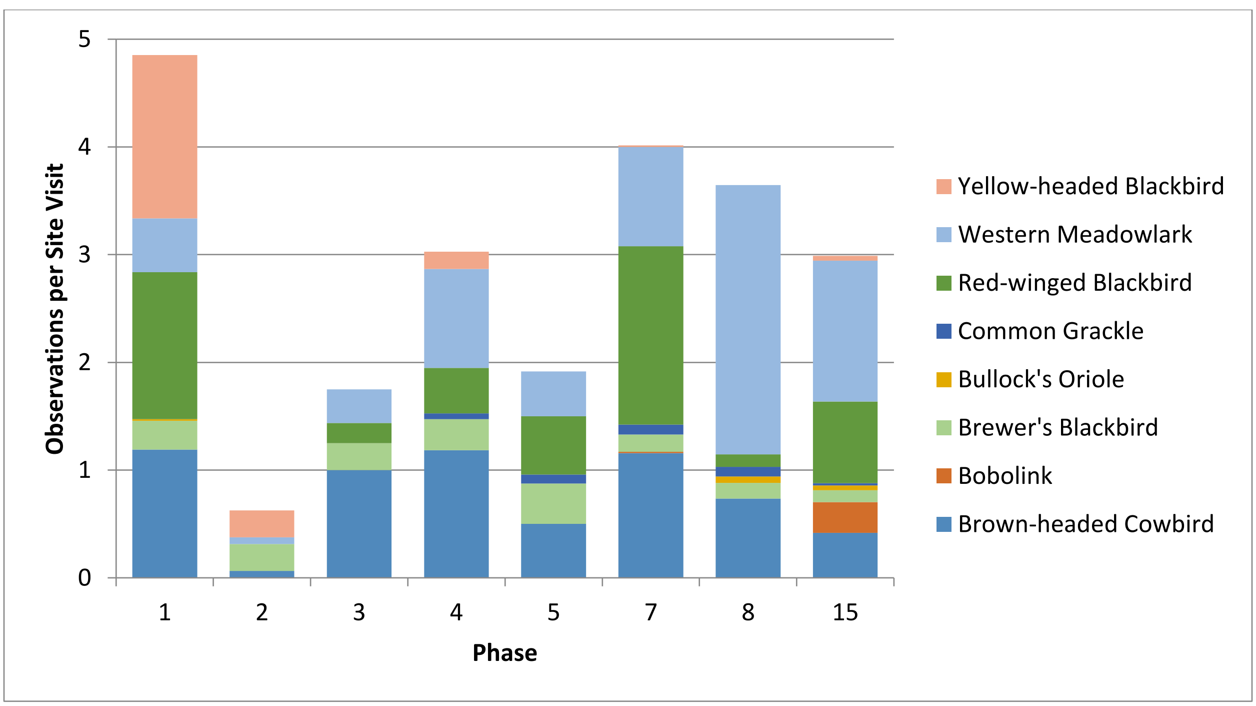

Figure 7-11. Relative abundance of blackbirds and orioles (Icteridae) by phase in the Clark Fork River Operable Unit, 2015-2017.

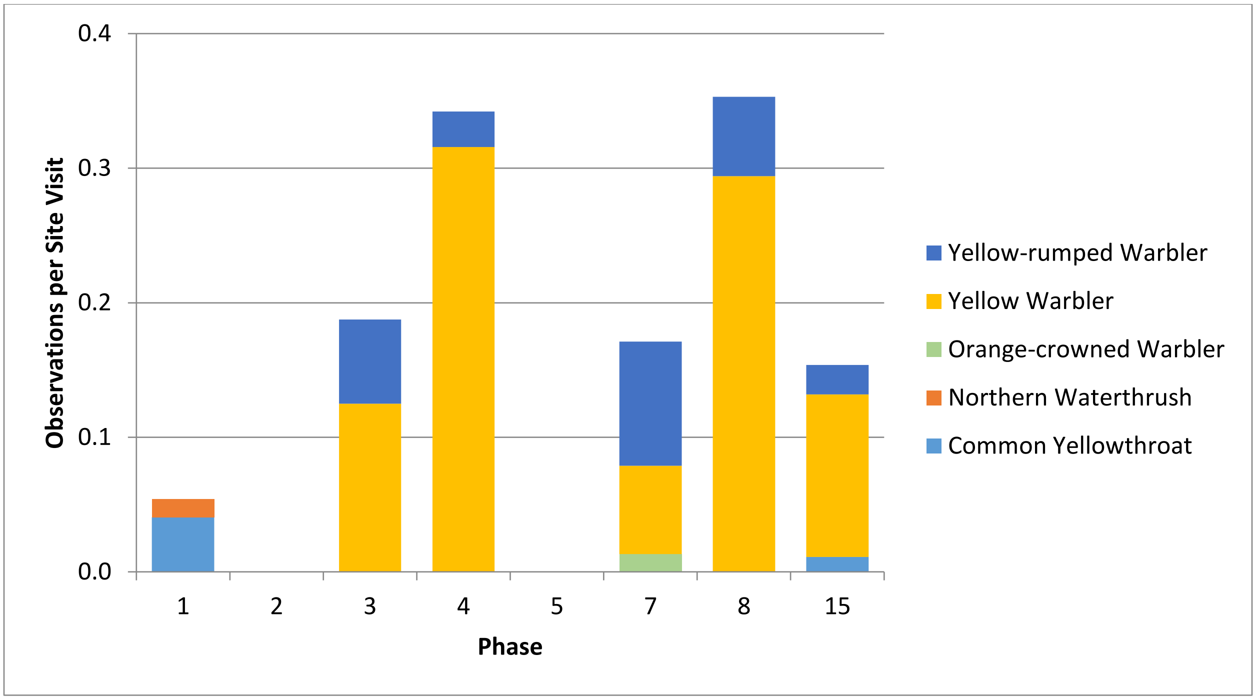

Figure 7-12. Relative abundance of warblers (Parulidae) by phase in the Clark Fork River Operable Unit, 2015-2017.

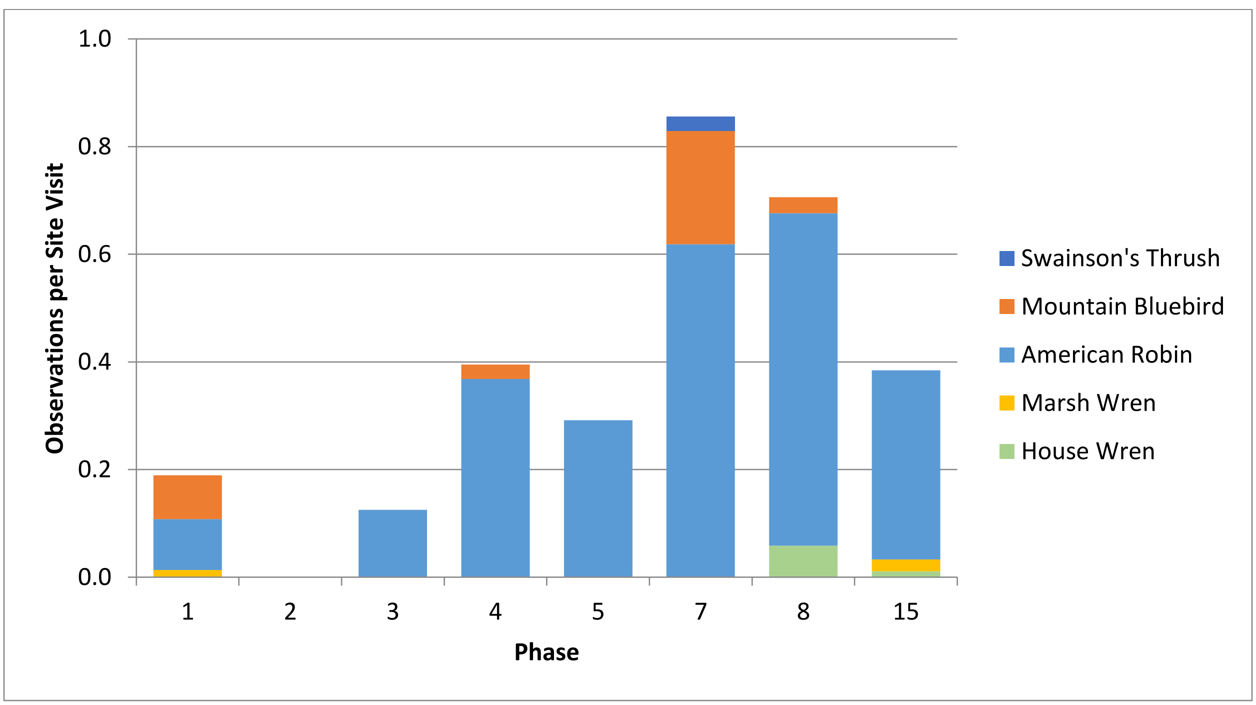

Figure 7-13. Relative abundance of wrens and thrushes (families Troglidytidae and Turdidae, respectively), by phase in the Clark Fork River Operable Unit, 2015-2017.

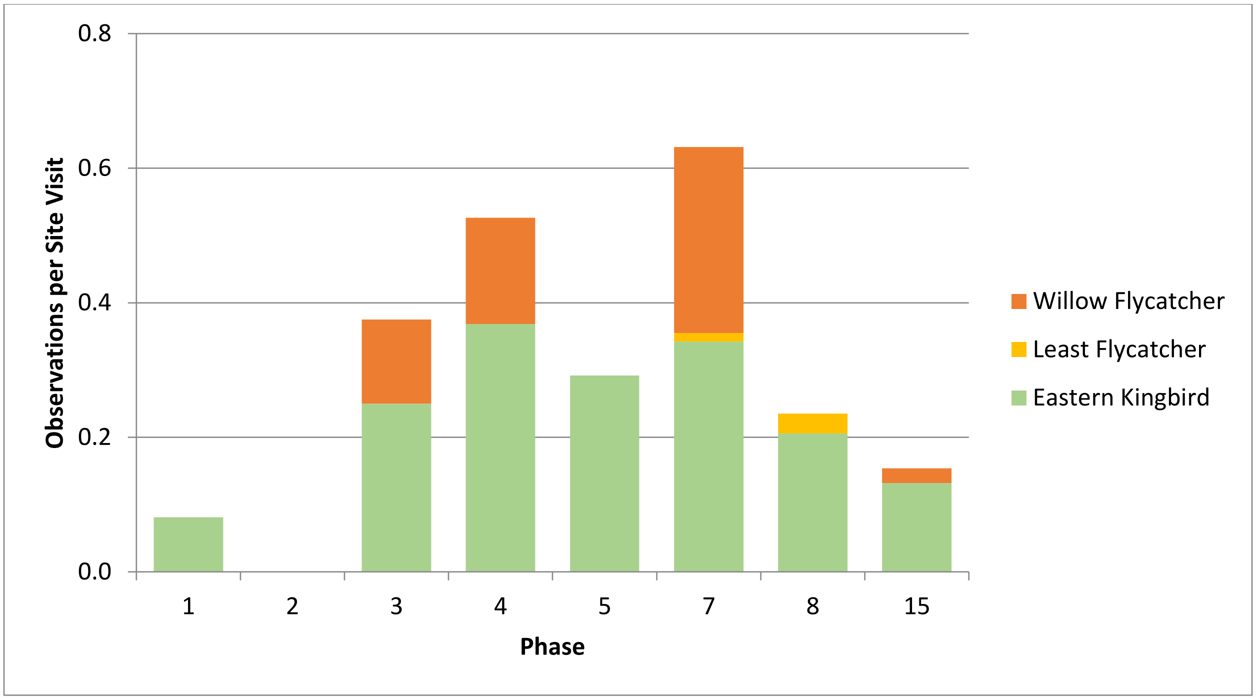

Figure 7-14. Relative abundance of tyrant flycatchers (Tyrannidae) by phase in the Clark Fork River Operable Unit, 2015-2017.

7.3.2.13 Pelicans, Herons, Ibises, and Cormorants

Three species in the Pelecaniformes order were observed in the CFROU between 2015-2017: American white pelican *Pelecanus erythrorhynchos*, great blue heron *Ardea herodias*, and white-faced ibis *Plegadis chihi* (Figure 7-15). Each of these species is a member of a different family: great blue heron (Ardeidae), American white pelican (Pelecanidae), and white-faced ibis (Threskiornithidae).

Great blue herons and American white pelicans were each observed in all but one phase and were fairly common (Figure 7-15). Only one white-faced ibis has been observed in the CFROU: in Phase 4 in April 2017. American white pelicans and white-faced ibis are both Species of Concern in Montana [MNHP, 2017].

One cormorant (Suliformes) species was observed in the CFROU between 2015-2017: the double-crested cormorant *Phalacrocorax auritus.* Double-crested cormorants were generally common and were identified in all phases of the CFROU (Figure 7-15). Cormorants have recently been reclassified into their own order and were previously classified within Pelecaniformes.

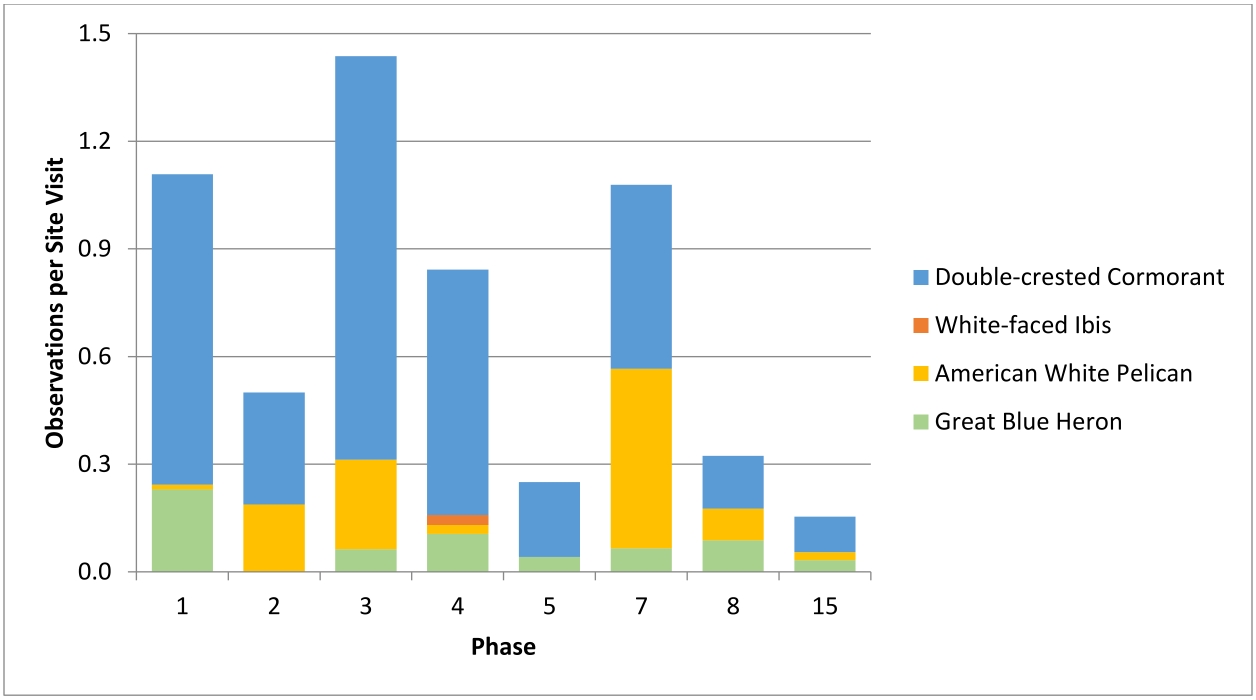

Figure 7-15. Relative abundance of large water birds (Pelecaniformes and Suliformes) by phase in the Clark Fork River Operable Unit, 2015-2017.

7.3.2.14 Woodpeckers

Three woodpecker species (Piciformes), all within the Picidae family, were observed in the CFROU between 2015-2017: red-naped sapsucker *Sphyrapicus nuchalis,* downy woodpecker *Picoides pubescens*, and northern flicker *Colaptes auratus* (Figure 7-16). Downy woodpecker and red-naped sapsucker were rare and were only identified in Phase 15 and Phase 1, respectively (Figure 7-16). Northern flicker were observed in all but two phases and were generally common (Figure 7-16).

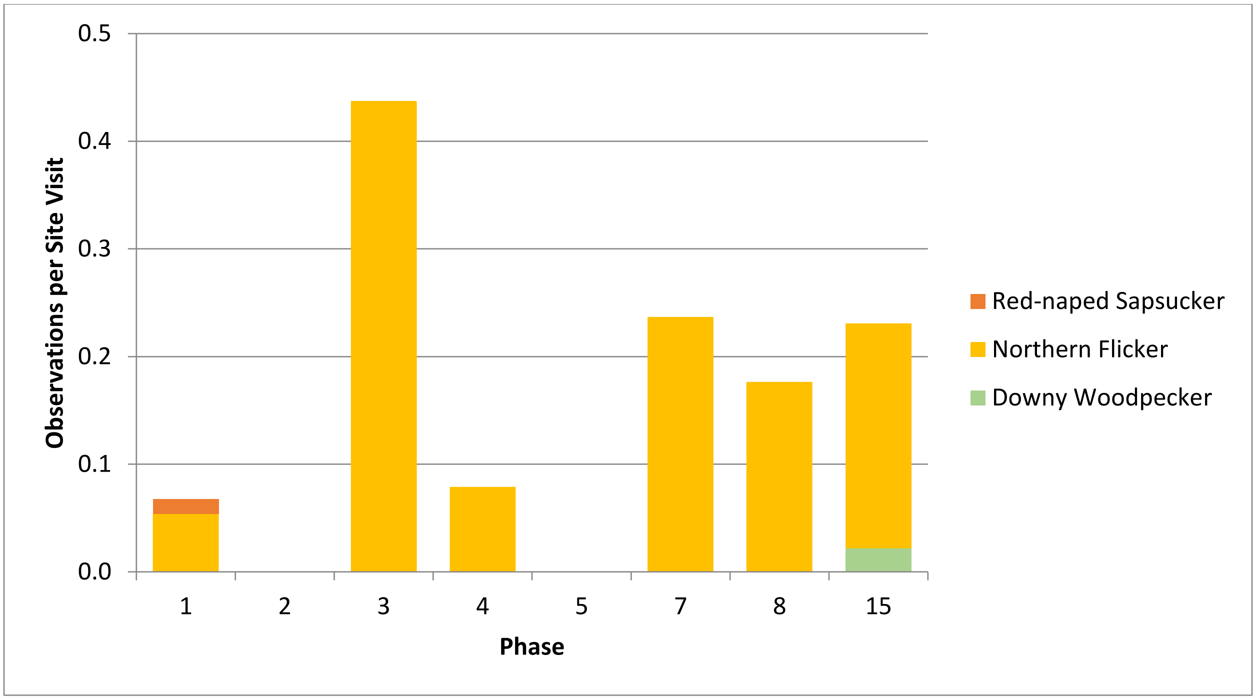

Figure 7-16. Relative abundance of woodpeckers (Piciformes) by phase in the Clark Fork River Operable Unit, 2015-2017.

7.3.2.15 Grebes

Three grebe species (Podicipediformes), all within the Podicipedidae family, were observed in the CFROU between 2015-2017: horned grebe *Podiceps auritus*, red-necked grebe *Podiceps grisegena*, and western grebe *Aechmophorus occidentalis* (Table 7-3). All grebe species were rare in the CFROU and almost all observations occurred in Phase 7, although one red-necked grebe was observed in Phase 2. The horned grebe is a "species of concern" in the state of Montana [MNHP, 2017]. Only one horned grebe has been observed in the CFROU and that individual was observed in Phase 7.

7.3.2.16 Owls

One owl (Strigiform) species was observed in the CFROU: a great horned owl *Bubo virginianus* in Phase 4 in April 2017. This individual was observed at 8:55 am.

7.3.3 Results for Species of Concern

Fourteen of the 115 (12%) are designated as Species of Concern or, in the case of bald eagles, as a Special Status Species by the MNHP [2017]. Phases 7 and 15 had the highest number of Species of Concern and were particularly important habitats for common loons and American white pelicans (Figure 7-17). Phase 15 provides valuable habitat for Bobolink (Figure 7-17). At least three Species of Concern, or Special Status Species, was observed in every phase except Phase 5 (Figure 7-17). In addition, two species observed in the CFROU are Potential Species of Concern: Barrow's goldeneye and hooded merganser. Both were common in some phases although not widely distributed among phases.

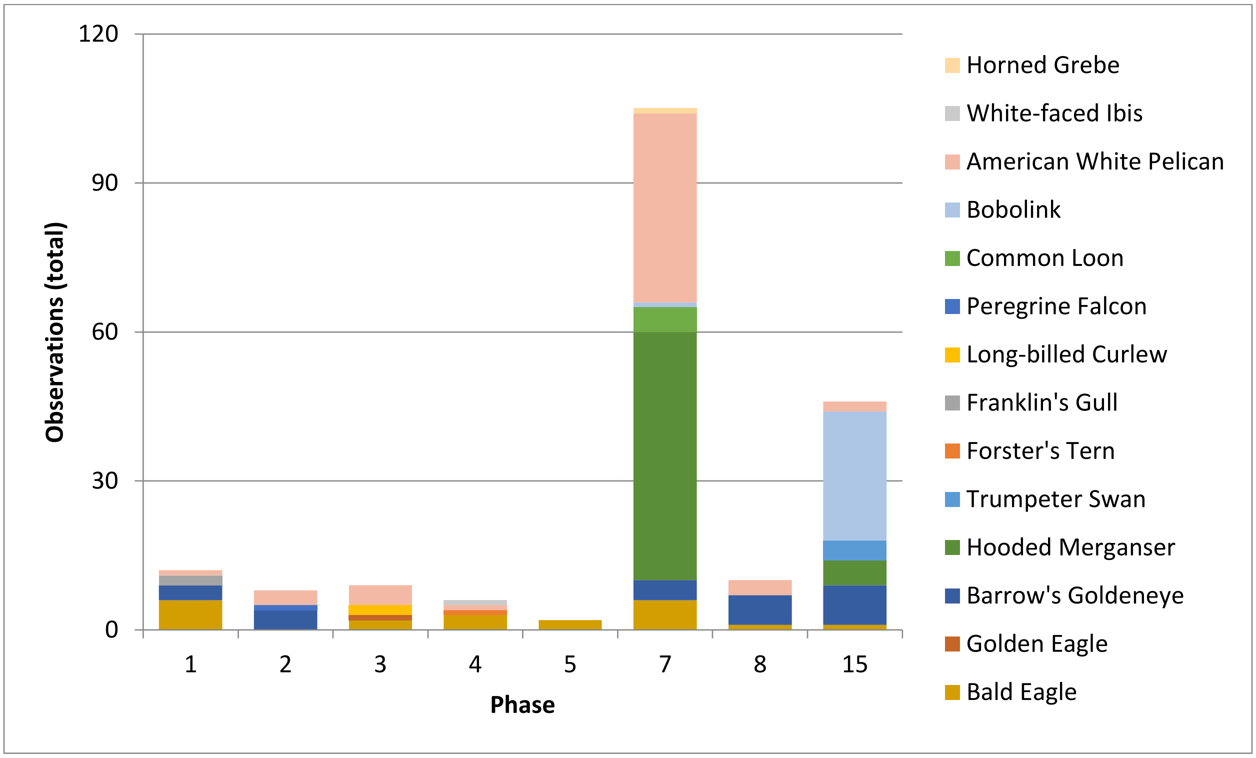

Figure 7-17. Relative abundance of Montana Species of Concern [MNHP, 2017] by phase in the Clark Fork River Operable Unit, 2015-2017.

7.4 DISCUSSION

The CFROU provides habitat for a large number of bird species including multiple Species of Concern. The CFROU provides important wetland and riparian habitat and the richness of water birds such as grebes, shorebirds, waders, and waterfowl is particularly high.

Within just three years of monitoring, and during a period of active remediation and construction, 115 bird species have been identified in the CFROU. Remedial actions will likely lead to greater species richness over the long term as contamination is reduced and habitat is restored. However, the influence of remedial actions on bird use in the CFROU in the short term is unknown. A reasonable assumption may be that short-term disturbance would deter bird use in the CFROU temporarily. At this point, it appears that construction and revegetation has not resulted in a substantial decline in bird use and that the bird assemblage is resilient to the level of disturbance posed by the remedy thus far. Some highly influential ecological theory predicts that moderate levels of disturbance may actually maximize species richness as habitats become heterogeneous [Connell, 1978; Wilkson, 1999]. Remediation, reconstruction, and revegetation, which is occurring at various times and in various locations, may provide a mosaic of habitat conditions and vegetation growth stages mimicking natural disturbance regimes in certain respects, and the heterogeneity in vegetation growth stages may encourage short term bird species richness.

Due to discrepancies in the number of site visits within each phase, comparisons of species richness or abundance are somewhat tenuous between phases. Based on estimates of richness after adjusting for sampling effort, it appears that species richness among phases was similar, although the species assemblage differed among phases. After adjusting for the number of site visits within each phase, Phases 4 and 7 appear to have a bit higher species richness than others and Phase 1 may have slightly lower richness. Increased richness in Phase 7 would likely be due to the Racetrack Pond which provides a unique habitat in the CFROU. Lower species richness in Phase 1 may be due to the intensity of construction activities that occurred in that river reach during the monitoring period, the relative lack of vegetation in the initial years after construction, or other factors.

Birds of prey (excluding owls) were well represented in the CFROU in these monitoring data, perhaps because these species are large and conspicuous. The particular assemblage of birds of prey in each phase was somewhat unique which may reflect variation in habitat and prey availability or strategies among individuals to minimize interference competition and other negative interactions with other birds of prey. The diversity and abundance of these predatory species, which occupy trophic positions at or near the top of the food chain, suggest the CFROU and adjacent areas are high quality habitat for small mammals, birds, and fish. Owls, which are essentially nocturnal birds of prey, were not well represented in these data, presumably due to limitations in sampling methods (i.e., daytime sampling). Given the high diversity of diurnal birds of prey in the CFROU, richness and abundance of owls in the CFROU is almost certainly higher than what is represented in these data.

Species of Concern in Montana were present throughout the CFROU and 14 such species have been observed since 2015. Phases 7 and 15 were particularly rich in these rare species but all phases had at least one observation of a Species of Concern, and most had at least three observations of separate Species of Concern. The richness and abundance of Species of Concern demonstrates the value of the CFROU for the conservation of rare ant threatened bird fauna in Montana.

In addition to degradation of habitat, harvesting of hay represent a major mortality issue, specifically for the Bobolink, a Montana Species of Concern. Bobolink nest in wet meadows and hay fields. When hay harvesting occurs prior to fledging of young, many bobolink are by mowers. Cutting fields after the fledging period may reduce mortality of bobolink. In addition, mowing fields from the inside out, rather than from the outside in, may reduce mortality by allowing birds to escape as opposed to concentrating birds within the field to be mowed.

8.0 VEGETATION

8.1 INTRODUCTION

Major remediation and revegetation in Phases 2, 5, and 6 of the Clark Fork River Operable Unit (CFROU) was completed in 2016. Vegetation monitoring data collected as part of this effort is intended to assess vegetation conditions as measured by specific metrics to evaluate progress toward attainment of vegetation performance targets. Monitoring in 2017 completed all Year-1 vegetation monitoring requirements specified by the CFROU Record of Decision [USEPA, 2004]. This report provides detailed methods and results for all vegetation monitoring activities conducted in 2017 in the CFROU.

8.2 METHODS

8.2.1 Monitoring Locations

In 2017, vegetation monitoring occurred in Phases 2, 5, and 6 which represented the first-year post-remediation (Year-1) in each of these project phases.

The performance standards for vegetation identified in the CFROU ROD are grouped according to "post-remedial land use and landscape position" [USEPA, 2004]. We have identified three specific vegetation zones corresponding to these "post-remedial land use and landscape position" groups identified in the ROD and have defined these vegetation zones corresponding to the specific vegetation performance standards (Table 8-1). The vegetation zone closest to the river is the "Riparian Zone", which is defined in the ROD as the "streambank riparian buffer zone" [USEPA, 20004], and includes the area from the streambank and extending laterally 50 feet from the streambank on either side of the river. All areas outside the Riparian Zone will either be identified as "Transition Zone" or "Upland Zone". Transition zone areas are those outside the Riparian Zone but within the floodplain. Vegetation in the Transition Zone would require access to water but not as extensively as vegetation in the Riparian Zone. The Upland Zone would be any areas outside the floodplain which are not as dependent on access to water.

Planted woody species survival will be monitored in ten sampling units ("survival plots") each covering a 100 m^2 area (10x10 m). Each survival plot was oriented parallel to the river bank and placed entirely within the Riparian Zone boundary and within overlapping areas where containerized plants were planted ("planting units") because the performance standard for this metric is specific to planted (rather than naturally recruited) woody plants [USEPA, 2004]. A systematic sampling design was used to determine survival plot locations to ensure that plots were approximately evenly spaced along the length of each phase. Within each phase, points along each side of the river bank were placed at 10 percent, 30 percent, 50 percent, 70 percent, and 90 percent of the linear distance from the phase start (upstream boundary at river intersection) to the phase end (downstream boundary at river intersection)[72]. At those points, (on each side of the river) a survival plot was located at the nearest planting unit[73] (either upstream or downstream) entirely within the overlapping area of the Riparian Zone and the planting unit. This approach for selecting survival plot locations is intended to provide an unbiased, accurate, standardized method for identifying survival sampling locations to estimate woody plant survival for the entire Riparian Zone of each phase, as specified by the ROD [USEPA, 2004]. It allows for comparison of survival among phases and among years. However, this approach is not intended to evaluate differences among planting units by habitat type as habitat types (other than those identified in the ROD) were not considered as a sampling strata in this design.

Total canopy cover of non-weed perennial vegetation in each phase was monitored in 60 small (1 m^2) plots ("transect subplots") within each phase. A systematic sampling design was used to determine all transect subplot locations to ensure that plots were approximately evenly spaced along the length of each phase and laterally across the floodplain. Within each phase, points along each side of the river bank were identified at 25 percent, 50 percent, and 75 percent of the linear distance from the phase start to the phase end. From each point (on each side of the river), lateral transects were extended 100 m in an east-west direction. Along each transect, beginning at 10 m from the river bank, points were located every 20 m and two paired transect subplots were located at each transect points. Transect subplots were located along an intersecting transect line at 0 m and 2 m. Thus, along each of the six transects within each phase, 20 transect subplots were sampled. For each transect subplot, field biologists identified the vegetation zone (i.e., Riparian, Transition, or Upland) as the performance standards for total canopy cover of non-weed perennial vegetation is specific for each zone. As with the approach for selecting survival plot locations, this systematic approach for identifying transect subplot locations for cover monitoring is intended to provide an unbiased, accurate, standardized method for identifying perennial veg cover sampling locations for each phase, as specified by the ROD [USEPA, 2004]. It allows for comparison of cover among vegetation zones, among phases, and among years. However, this approach is not intended to evaluate differences in cover by any other sampling strata as those were not considered in this sampling.

[72] These points were determined prior to visiting the site using standard GIS tools and layers. Field biologists navigated to these points using field GPS units.

[73] The nearest planting units to each point were identified in the field.

Table 8-1. Vegetation minimum performance standards and guidelines for monitoring metrics in the Clark Fork River Operable Unit [USEPA, 2004].

Vegetation Zone	Monitoring Metric	Year (Post-remediation)						
		1	2	3	4	5	7	10
Riparian[a]	Planted woody species survival (%)[b]	90	90	—	—	—	—	—
	Preferred woody species canopy cover (%)	—	—	—	—	50	60	80
	Total canopy cover of non-weed perennial vegetation (%)	90	95	—	98	98	98	98
Transition[c]	Total canopy cover of non-weed perennial vegetation (%)	90	95	98	—	98	—	—
Upland[d]	Noxious weed cover (%)							<5
	Total canopy cover of non-weed perennial vegetation (%)							45
	Species richness (per 100 square meters)[e]							5

(a) The Riparian Zone performance standards correspond to Exhibit 2-26 in the ROD [USEPA, 2004]. The Riparian Zone is defined as a polygon extending 50 feet laterally from the streambank on each side of the river in each remedial area. The Riparian Zone corresponds to the Streambank Riparian Buffer Zone, which is described in the ROD.

(b) The ROD specifies replanting criteria for the fourth, fifth, and seventh years instead of monitoring for this metric [USEPA, 2004].

(c) The Transition Zone performance standards are identified in the ROD in Exhibit 2-27 [USEPA, 2004]. This zone will be defined in the field as any portion of the floodplain between the riparian zone and the 100-year floodplain.

(d) This vegetation zone corresponds to performance standards identified in the ROD in Exhibit 2-28 [USEPA, 2004]. Specific timelines for attaining performance standards in Exhibit 2-28 were not identified [USEPA, 2004].

(e) Each species must account for more than 1 percent cover to be counted toward this metric; noxious weeds are not counted toward this metric. This metric does not apply in areas intended for agricultural crop production.

8.2.2 Monitoring Schedule

Vegetation monitoring occurred from August 14-17, 2017.

8.2.3 Monitoring Parameters

Two parameters were monitored in the CFROU in 2017: planted woody species survival and total canopy cover of non-weed perennial vegetation. Each has a specific Year-1 performance target and monitoring in 2017 for each metric was restricted to the vegetation zones where the performance targets were applicable (Table 8-1).

8.2.4 Sample Collection and Analysis

8.2.4.1 Woody Species Survival

In each survival plot (located in planting units within the Riparian Zone), each containerized woody plant was evaluated to determine plant species and survival. Plants which were rooted partially on the plot boundaries were considered within the plot if at least 50 percent of the plant's roots were assumed to be inside the plot. A photo was taken of each survival plot following sampling.

8.2.4.2 Total Canopy Cover of Non-Weed Perennial Vegetation

Within each transect subplot, the vegetation zone was determined (i.e., Riparian, Transition, and Upland) and visual estimates of herbaceous cover percentage were made for each perennial plant species. A photo was taken of each transect subplot following sampling.

8.2.5 Data Analysis

8.2.5.1 Precipitation

Available streamflow, climate, and precipitation data were gathered from available sources and summarized to provide context for the 2017 vegetation monitoring results.

8.2.5.2 Woody Species Survival

Average (mean) survival was determined for all species collectively within each phase as the metric for evaluation of the "planted woody species survival" performance target. In addition, survival was averaged for each species within each phase to assist project managers in determining suitable species for Riparian Zone planting.

8.2.5.3 Total Canopy Cover of Non-Weed Perennial Vegetation

All identified species in each transect subplot were classified as "desirable", "undesirable", or "noxious". Desirable species were defined as: (1) any native plant according to MNHP [2017]; (2) any non-native plant identified by the Montana Natural Heritage Program (MNHP) to be "relatively benign" based on the *C*-value[74]; or (3) any plant identified in a seed-mix for the CFROU. Undesirable species were defined as: (1) any species listed as a weed in Deer Lodge, Powell, or Granite Counties; (2) any species listed as the Montana Department of Agriculture Noxious Weed list as "Rank 3"[75], or (3) any species with *C*-value corresponding to "invasive"

[74] The *C*-value is the Montana Coefficient of Conservatism value and are defined in: http://fieldguide.mt.gov/statusCodes.aspx?scrollto=cvalue)

[75] A "regulated plant" but not a "noxious weed" according to MDA [2015].

according to MNHP. Noxious weeds were defined as any identified specifically as noxious plants by MDA [2015]. Based on these classifications, average cover percentage of each species class within each vegetation zone was determined and compared to the performance targets for each zone.

8.3 RESULTS

8.3.1 Precipitation

The Deer Lodge valley is classified as having a “Continental, warm-summer” or “Dfb” climate [Weatherbase, 2018] according to the widely-accepted Koppenen climate classification scale [Kottek et al., 2006]. This climate type is common in western plains and mountain states of the U.S. and is similar to “cold semi-arid steppe” or “BSk” climates, although with slightly more precipitation. Deer Lodge tends to have low annual precipitation (median = 243 mm; 9.6 inches) most of which accumulates during the months of May and June (Figure 8-1).

Annual precipitation in 2017 at Deer Lodge was 171 mm (6.8 inches) which was below the long-term median, but within the interquartile range (i.e., between the 25th and 75th percentiles) for the period of record. However, monthly precipitation was erratic in 2017. Precipitation during the months of May and June, which are critical for establishment of vegetation in this region, was about average (41 mm; 1.6 inches) in May and high (76 mm; 3.0 inches) in June (Figure 8-1). However, this relatively wet spring was followed by severe drought throughout the summer and early fall. No precipitation was measured in Deer Lodge during a four-month period from July through October of 2017 (Figure 8-1). Vegetation monitoring occurred in mid-August and was preceded by a period of 62 days with essentially no precipitation [U.S. Climate Data, 2018]. Following the monitoring period, no measurable precipitation occurred for another 74 days [U.S. Climate Data, 2018].

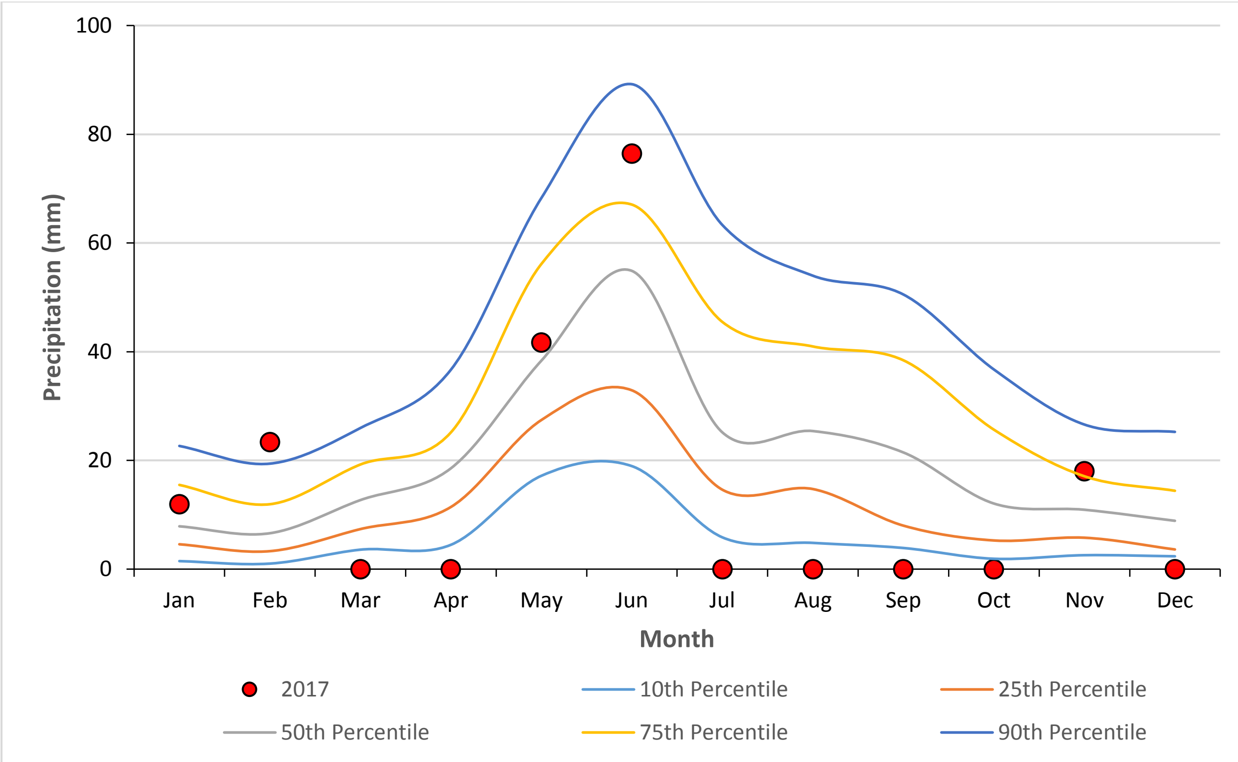

Figure 8-1. Monthly precipitation at Deer Lodge, Montana in 2017 compared to the period of record (1939-2013). Data sources were: USDA [2018] (for period of record) and U.S. Climate Data (for 2017).

8.3.2 Woody Plant Survival

In 2017, 30 survival plots were monitored for woody plant survival in the CFROU. Ten plots were monitored in each phase. In total, 384 woody plants were monitored among the three phases. Survival was below the Year-1 Riparian Zone performance target (90 percent) for planted woody species survival (90 percent) in all phases in 2017. Mean survival was 87.4 percent in Phase 2, 71.6 percent in Phase 5, and 86.9 percent in Phase 6 (Table 8-2).

In Phase 2, nine species were identified including: speckled alder *Alnus incana,* spring birch *Betula occidentalis,* red-oiser dogwood *Cornus stolonifera,* black cottonwood *Populus balsamifera,* quaking aspen *Populus tremuloides,* inland gooseberry *Ribes setosum,* Wood's rose *Rosa woodsii,* willow *Salix* (not identified to species), and silver buffaloberry *Sheperdia argentea.* Willow were about seven times more common than other planted woody species. Most of the dead woody plants in Phase 2 were not identified to species so it is difficult to evaluate survival by species. Inland gooseberry survival was no more than 86 percent in Phase 2.

In Phase 5, 10 species were identified including: Wyoming big sagebrush *Artemisia tridentate,* spring birch, red-oiser dogwood *Cornus stolonifera*, shrubby cinquefoil *Dasiphora floribunda,* black cottonwood, golden currant *Ribes aureum*, inland gooseberry, Wood's rose, willow, and silver buffaloberry. As in Phase 2, most dead plants in Phase 5 could not be identified to species. However, despite uncertainty in the species of the majority of the dead plants, survival of several species was clearly below the performance target in Phase 5. Spring birch, red-oiser dogwood, and Wood's rose survival was no more than 67 percent in Phase 5.

In Phase 6, 10 species were identified including: speckled alder, spring birch, red-oiser dogwood, shrubby cinquefoil, black cottonwood, quaking aspen, golden currant, inland gooseberry, willow, and silver buffaloberry. Survival of most species in Phase 6 appeared to be above, or near, the Year-1 performance target but uncertainty in the species of some dead plants confounds evaluation of survival by species to some degree in Phase 6.

Table 8-2. Woody plant survival in riparian survival plots from the Clark Fork River Operable Unit, 2017. Survival was monitored in ten 100-m² plots in each phase.

Common Name	Taxonomic Name	Plants (counts)				Survival (%)
		Alive	Unknown	Dead	Total	
Phase 2						
Speckled Alder	*Alnus incana*	6	0	0	6	100
Spring Birch	*Betula occidentalis*	6	0	0	6	100
Red-oiser Dogwood	*Cornus stolonifera*	9	0	0	9	100
Black Cottonwood	*Populus balsamifera*	5	0	0	5	100
Quaking Aspen	*Populus tremuloides*	10	0	0	10	100
Inland Gooseberry	*Ribes setosum*	12	0	2	14	85.7
Wood's rose	*Rosa woodsii*	1	0	0	1	100
Willow	*Salix*	71	0	2	73	97.3
Silver Buffaloberry	*Sheperdia argentea*	4	0	0	4	100
Unknown		1	0	14	15	6.7
Total		**125**	**0**	**18**	**143**	**87.4**
Phase 5						
Wyoming Big Sagebrush	*Artemisia tridentata*	6	0	0	6	100
Spring Birch	*Betula occidentalis*	4	0	3	7	57.1
Red-oiser Dogwood	*Cornus stolonifera*	2	0	1	3	66.7
Shrubby Cinquefoil	*Dasiphora floribunda*	4	0	0	4	100
Black Cottonwood	*Populus balsamifera*	12	0	1	13	92.3
Golden Currant	*Ribes aureum*	2	0	0	2	100
Inland Gooseberry	*Ribes setosum*	4	0	0	4	100
Wood's rose	*Rosa woodsii*	2	0	1	3	66.7
Willow	*Salix*	26	0	0	26	100

Common Name	Taxonomic Name	Plants (counts)				Survival (%)
		Alive	Unknown	Dead	Total	
Silver Buffaloberry	*Sheperdia argentea*	4	0	0	4	100
Unknown		2	0	21	23	8.7
Total		**68**	**0**	**27**	**95**	**71.6**
Phase 6						
Speckled Alder	*Alnus incana*	11	0	0	11	100
Spring Birch	*Betula occidentalis*	9	0	1	10	90
Red-oiser Dogwood	*Cornus stolonifera*	17	0	1	18	94.4
Shrubby Cinquefoil	*Dasiphora floribunda*	1	0	0	1	100
Black Cottonwood	*Populus balsamifera*	31	0	3	34	91.2
Quaking Aspen	*Populus tremuloides*	5	0	0	5	100
Golden Currant	*Ribes aureum*	5	0	0	5	100
Inland Gooseberry	*Ribes setosum*	4	0	0	4	100
Willow	*Salix*	40	1	5	46	87
Silver Buffaloberry	*Sheperdia argentea*	3	0	0	3	100
Unknown		0	0	8	8	0
Total		**126**	**1**	**18**	**145**	**86.9**

8.3.3 Total Canopy Cover of Non-Weed Perennial Vegetation

8.3.3.1 Phase 2

In 2017, 60 transect subplots were monitored for canopy cover of perennial vegetation in Phase 2 including: 21 subplots in the Riparian Zone, 35 subplots in the Transition Zone, and 4 subplots in the Upland Zone.

In the Riparian Zone, total canopy cover of non-weed[76] perennial vegetation was 26.2 percent, 4.7 percent of which was the undesirable species Mexican kochia *Kochia scoparia* (Table 8-4). Noxious weed cover was 0.2 percent and comprised entirely of knotweed *Polygonum* (Table 8-4). Common (at least 2 percent average cover) desirable species were common yarrow *Achillea millefolium,* oakleaf goosefoot *Chenopodium glaucum,* slender wheatgrass *Elymus trachycaulus,* and narrowleaf willow *Salix exigua.*

In the Transition Zone, total canopy cover of non-weed perennial vegetation was 27.8 percent, 5.4 percent of which were undesirable species (Table 8-5). No noxious weed cover was observed. Common desirable species were oakleaf goosefoot, Baltic rush *Juncus balticus*, grass species *Poaceae*, and bulrush *Schoenoplectus.* Common undesirable species included Mexican kochia.

In the Upland Zone, total canopy cover of non-weed perennial vegetation was 16.3 percent, 9.5 percent of which were undesirable species including Mexican kochia, which was common (Table 8-6). No noxious weed cover was observed. The only desirable species were grasses.

[76] For purposes of evaluation with respect to the ROD performance targets, we considered "weeds" to be only those listed as MDA [2015] noxious weeds. "Undesirable" species, although summarized separately from desirable species, were not considered weeds with respect to the performance target goals.

Table 8-3. Total canopy cover of perennial vegetation in transect subplots (1-m^2) within the Phase 2 Riparian Zone (n = 21) of the Clark Fork River Operable Unit, August 2017.

Common Name	Taxonomic Name	Cover (%)	
		Standard Deviation	Mean
Desirable Species			
Grass species	*Poaceae* spp	2.0	1.4
Common yarrow	*Achillea millefolium*	7.7	3.8
Speckled alder	*Alnus incana*	5.3	1.7
Fringed sagebrush	*Artemisia frigida*	1.1	0.2
Mustard	*Brassica* species	0.9	0.2
Oakleaf goosefoot	*Chenopodium glaucum*	10.1	7.1
Rocky Mountain bee plant	*Cleome serrulata*	1.1	0.2
Slender wheatgrass	*Elymus trachycaulus*	8.5	4.7
Prairie flax	*Linum lewisii*	0.2	0.0
Narrowleaf willow	*Salix exigua*	6.0	2.1
Desirable Species Total			**21.5**
Undesirable Species			
Mexican kochia	*Kochia scoparia*	10.4	4.7
Undesirable Species Total			**4.7**
Noxious Weeds			
Knotweed	*Polygonum* species	0.9	0.2
Noxious Species Total			**0.2**

Table 8-4. Total canopy cover of perennial vegetation in transect subplots (1-m^2) within the Phase 2 Transition Zone (*n* = 35) of the Clark Fork River Operable Unit, August 2017.

Common Name	Taxonomic Name	Cover (%)	
		Standard Deviation	Mean
Desirable Species			
Common yarrow	*Achillea millefolium*	0.5	0.1
Sedge	*Carex* species	3.4	0.6
Oakleaf goosefoot	*Chenopodium glaucum*	9.1	3.6
Rocky Mountain bee plant	*Cleome serrulata*	1.1	0.4
Slender wheatgrass	*Elymus trachycaulus*	3.0	0.7
Baltic rush	*Juncus balticus*	22.5	7.7
Prairie flax	*Linum lewisii*	0.2	0.0
Grass species	*Poaceae* species	10.5	5.9
Inland gooseberry	*Ribes setosum*	3.4	0.6
Bulrush	*Schoenoplectus* species	6.1	2.1
American speedwell	*Veronica americana*	0.2	0.0
Rush	*Juncus* species	3.4	0.6
Desirable Species Total			**22.4**
Undesirable Species			
White sweet clover	*Melilotus albus*	0.5	0.1
Redtop	*Agropryon stolonifera*	1.7	0.3
Mexican kochia	*Kochia scoparia*	11.0	4.9
Black bindweed	*Polygonum convolvulus*	0.2	0.0
Small tumble-mustard	*Sisymbrium loeselii*	0.2	0.0
Common dandelion	*Taraxacum officinale*	0.2	0.0
Undesirable Species Total			**5.4**

Table 8-5. Total canopy cover of perennial vegetation in transect subplots (1-m^2) within the Phase 2 Upland Zone (n = 4) of the Clark Fork River Operable Unit, August 2017.

Common Name	Taxonomic Name	Cover (%)	
		Standard Deviation	Mean
Desirable Species			
Grass species	*Poaceae* species	7.0	6.8
Desirable Species Total			**6.8**
Undesirable Species			
Mexican kochia	*Kochia scoparia*	10.6	9.3
Clasping pepper-grass	*Lepidium perfoliatum*	0.5	0.3
Undesirable Species Total			**9.5**

8.3.3.2 Phase 5

In 2017, 60 transect subplots were monitored for canopy cover of perennial vegetation in Phase 5 including: 16 subplots in the Riparian Zone and 44 subplots in the Transition.

In the Riparian Zone, total canopy cover of non-weed perennial vegetation was 36.6 percent, 12.2 percent of which were undesirable species (Table 8-6). No noxious weed cover was observed. Common desirable species included common yarrow and slender wheatgrass *Elymus trachycaulussle.* Common undesirable species included white sweetclover *Melilotus albus*.

In the Transition Zone, total canopy cover of non-weed perennial vegetation was 32.2 percent, 4.3 percent of which were undesirable species (Table 8-7). Noxious weed cover was 0.05 percent and included leafy spurge *Euphorbia esula* and yellowflag iris *Iris pseudacorus* (Table 8-7). Each noxious weed was observed in one transect subplot at 1 percent cover. Common desirable species were slender wheatgrass and other grasses.

Table 8-6. Total canopy cover of perennial vegetation in transect subplots (1-m²) within the Phase 5 Riparian Zone (*n* = 16) of the Clark Fork River Operable Unit, August 2017.

Common Name	Taxonomic Name	Cover (%)	
		Standard Deviation	Mean
Desirable Species			
Common yarrow	*Achillea millefolium*	5.4	2.3
Fringed sagebrush	*Artemisia frigida*	0.5	0.2
Slender wheatgrass	*Elymus trachycaulus*	15.4	19.0
Wild licorice	*Glycyrrhiza lepidota*	2.5	0.6
Foxtail barley	*Hordeum jubatum*	0.5	0.1
Grass species	*Poaceae* species	1.3	0.4
Narrowleaf willow	*Salix exigua*	6.2	1.8
Desirable Species Total			**24.4**
Undesirable Species			
White sweetclover	*Melilotus albus*	13.2	11.9
Field pennycress	*Thlaspi arvense*	1.3	0.3
Undesirable Species Total			**12.2**

Table 8-7. Total canopy cover of perennial vegetation in transect subplots (1-m²) within the Phase 5 Transition Zone (*n* = 44) of the Clark Fork River Operable Unit, August 2017.

Common Name	Taxonomic Name	Cover (%)	
		Standard Deviation	**Mean**
Desirable Species			
Common yarrow	*Achillea millefolium*	1.7	0.5
Fringed sagebrush	*Artemisia frigida*	0.8	0.2
Sedge	*Carex* species	4.4	0.7
Oakleaf goosefoot	*Chenopodium glaucum*	0.8	0.1
Creeping spikerush	*Eleocharis palustris*	0.3	0.0
Slender wheatgrass	*Elymus trachycaulus*	17.1	19.3
American mannagrass	*Glyceria grandis*	7.5	1.1
Foxtail barley	*Hordeum jubatum*	0.3	0.1
Grass species	*Poaceae* species	15.9	3.8
Water Smartweed	*Polygonum amphibium*	0.8	0.1
Buttercup	*Ranunculus* species	8.1	1.6
Curly dock	*Rumex crispus*	1.4	0.2
Cattail	*Typha latifolia*	0.8	0.2
Desirable Species Total			**27.9**
Undesirable Species			
Redtop	*Agropryon stolonifera*	7.4	1.5
Mexican kochia	*Kochia scoparia*	3.8	0.9
White sweetclover	*Melilotus albus*	4.4	1.8
Common dandelion	*Taraxacum officinale*	0.2	0.0
Field pennycress	*Thlaspi arvense*	0.3	0.0
Undesirable Species Total			**4.3**
Noxious Species			
Leafy spurge	*Euphorbia esula*	0.2	0.02
Yellowflag iris	*Iris pseudacorus*	0.2	0.02
Noxious Species Total			**0.05**

8.3.3.3 Phase 6

In 2017, 60 transect subplots were monitored for canopy cover of perennial vegetation in Phase 5 including: 14 subplots in the Riparian Zone, and 44 subplots in the Transition Zone, and 2 subplots in the Upland Zone.

In the Riparian Zone, total canopy cover of non-weed perennial vegetation was 19.7 percent, 6.7 percent of which were undesirable species (Table 8-8). Noxious weed cover was 0.1 percent from perennial pepperweed *Lepidium latifolium* (Table 8-8). Common desirable species included slender wheatgrass. Common undesirable species included white sweetclover and Mexican kochia.

In the Transition Zone, total canopy cover of non-weed perennial vegetation was 35.8 percent, 6.8 percent of which were undesirable species (Table 8-9). Noxious weed cover was 1.7 percent from knotweed (Table 8-9). Common desirable species were slender wheatgrass, Baltic rush, and other grasses. Common undesirable species included Mexican kochia.

In the Upland Zone, total canopy cover of non-weed perennial vegetation was 13.5 percent, 5.0 percent of which were undesirable species including Mexican kochia which was common (Table 8-10). Noxious weed cover was 1.5 percent from perennial pepperweed (Table 8-10). The only desirable species was slender wheatgrass.

Table 8-8. Total canopy cover of perennial vegetation in transect subplots (1-m^2) within the Phase 6 Riparian Zone (*n* = 14) of the Clark Fork River Operable Unit, August 2017.

Common Name	Taxonomic Name	Cover (%)	
		Standard Deviation	Mean
Desirable Species			
Slender wheatgrass	*Elymus trachycaulus*	14.3	11.3
Hairy willowherb	*Epilobium ciliatum*	0.5	0.1
Grass species	*Poaceae* species	2.7	0.9
Narrowleaf willow	*Salix exigua*	1.2	0.4
Desirable Species Total			**12.8**
Undesirable Species			
Prickly lettuce	*Lactuca serriola*	0.4	0.2
Redtop	*Agropryon stolonifera*	2.2	0.8
Mexican kochia	*Kochia scoparia*	5.6	3.2
White sweetclover	*Melilotus albus*	5.2	2.5
Undesirable Species Total			**6.7**
Noxious Species			
Perennial pepperweed	*Lepidium latifolium*	0.5	0.1
Noxious Species Total			**0.1**

Table 8-9. Total canopy cover of perennial vegetation in transect subplots (1-m^2) within the Phase 6 Transition Zone (n = 44) of the Clark Fork River Operable Unit, August 2017.

Common Name	Taxonomic Name	Cover (%)	
		Standard Deviation	**Mean**
Desirable Species			
Common yarrow	*Achillea millefolium*	0.9	0.2
Fringed sagebrush	*Artemisia frigida*	0.3	0.0
Oakleaf goosefoot	*Chenopodium glaucum*	6.0	1.0
Rocky Mountain bee plant	*Cleome serrulata*	6.7	1.4
Slender wheatgrass	*Elymus trachycaulus*	22.8	15.1
Wild licorice	*Glycyrrhiza lepidota*	4.2	0.9
Baltic rush	*Juncus balticus*	11.4	2.6
Indian ricegrass	*Oryzopsis hymenoides*	4.0	0.8
Common plantain	*Plantago major*	3.3	0.7
Grass species	*Poaceae* species	16.2	5.9
Bebb willow	*Salix bebbiana*	0.8	0.1
Cattail	*Typha latifolia*	1.5	0.3
Desirable Species Total			**29.0**
Undesirable Species			
Redtop	*Agropryon stolonifera*	5.6	1.5
Mexican kochia	*Kochia scoparia*	9.2	4.3
Clasping pepper-grass	*Lepidium perfoliatum*	4.1	0.6
White sweetclover	*Melilotus albus*	1.5	0.2
Black bindweed	*Polygonum convolvulus*	0.3	0.0
Small tumble-mustard	*Sisymbrium loeselii*	0.8	0.1
Undesirable Species Total			**6.8**
Noxious Species			
Knotweed complex	*Polygonum* species	11.3	1.7
Noxious Species Total			**1.7**

Table 8-10. Total canopy cover of perennial vegetation in transect subplots (1-m2) within the Phase 6 Upland Zone (n = 2) of the Clark Fork River Operable Unit, August 2017.

Common Name	Taxonomic Name	Cover (%)	
		Standard Deviation	Mean
Desirable Species			
Slender wheatgrass	*Elymus trachycaulu*	9.2	8.5
Desirable Species Total			**8.5**
Undesirable Species			
Cheatgrass	*Bromus tectorum*	4.9	3.5
Small tumble-mustard	*Sisymbrium loeselii*	2.1	1.5
Undesirable Species Total			**5.0**
Noxious Weeds			
Perennial pepperweed	*Lepidium latifolium*	2.1	1.5
Noxious Species Total			**1.5**

8.4 DISCUSSION

Vegetation monitoring in Phase 2, 5, and 6 of the CFROU in 2017 represented Year-1 (post-remedy) conditions and was focused on two metrics: woody plant survival in the Riparian Zone and total canopy cover of non-weed perennial vegetation in the Riparian and Transition Zones. The Year-1 performance targets for each of these metrics is 90 percent.

Mean woody plant survival was 87.4 percent in Phase 2, 71.6 percent in Phase 5, and 86.9 percent in Phase 6 and therefore each phase failed to achieve the Year-1 performance target. Survival in Phases 2 and 6 were close to the performance target whereas survival in Phase 5 was lower. Spring birch, red-oiser dogwood, and Wood's rose had particularly low survival in Phase 5 although relatively few individual plants of those species were monitored.

Compared to the performance targets, total canopy cover of non-weed perennial vegetation in was very low (less than 38 percent) in each vegetation zone of each phase. The average cover proportion provided by undesirable species in the three phases ranged from 18-34 percent in the Riparian Zones, from 7-19 percent in the Transition Zones, and from 37-58 percent in the Upland Zones. Mexican kochia was a common undesirable species in all vegetation zones. Additional undesirable species that were common in specific zones included sweetclover (Riparian Zones) and cheatgrass (Upland Zones). Slender wheatgrass and other grasses were common desirable species in all vegetation zones. Other desirable species that were common in the Riparian Zones included common yarrow, oakleaf goosefoot, narrowleaf willow, Baltic rush, and bulrush.

Summer drought conditions almost certainly contributed to the low cover percentages in these phases in in 2017. Summer drought was offset to some degree by a wet spring and strong runoff. Spring runoff and precipitation was above average, but not extreme, in 2017. However, those favorable conditions were followed by severe summer drought. In the Clark Fork River at the peak of the snowmelt period in 2017 streamflows were strong near Galen (approximately 900 ft^3/s) and at Deer Lodge (approximately 1,700 ft^3/s) and the magnitude of the runoff overall was generally above the long-term median (see Chapter 2.0). These conditions likely resulted in extensive, moderate flooding of the Riparian Zone in each phase providing and extended period of soil saturation. In addition, precipitation in May and June of 2017 was adequate providing soil moisture for vegetation in higher elevation portions of each phase (i.e., Transition and Upland Zones). Precipitation was about average in May and well above average (approximately 80th percentile) in June. However, after mid-June a 136-day period with essentially no precipitation followed. Monitoring occurred from day-63 to day-67 of this drought period and certainly contributed to the poor overall condition of the vegetation during the monitoring period. The drought likely had a particularly strong influence on perennial vegetation cover as those plants have shallower roots and the upper layers of soil were likely extremely dry during the August monitoring period.

Noxious weeds were generally well controlled in these phases. Mean noxious weed cover was less than 2 percent in each vegetation zone in each phase. Four noxious weed species were observed among the 180 subplots monitored: leafy spurge, yellowflag iris, perennial pepperweed, and knotweed. Leafy spurge, a MDA [2015] “2B” noxious weed[77], was observed one subplot at an estimated cover of 1 percent. Yellowflag iris, a MDA [2015] “2A” noxious weed[78], was also observed in one subplot at an estimated cover of 1 percent. Perennial pepperweed, also a MDA [2015] “2A” noxious weed, was observed in two subplots at cover proportions of 2 percent and 3 percent. Knotweed, a MDA [2015] “1B” noxious weed[79], was observed in two subplots at estimated cover of 4 percent and 75 percent.

[77] According to MDA [2015], "These weeds are abundant in Montana and widespread in many counties. Management criteria will require eradication or containment where less abundant. Management shall be prioritized by local weed districts."

[78] According to MDA [2015], "These weeds are common in isolated areas of Montana. Management criteria will require eradication or containment where less abundant. Management shall be prioritized by local weed districts."

[79] According to MDA [2015], "These weeds have limited presence in Montana. Management criteria will require eradication or containment and education."

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